Juvenile Salmon Survey, 1998, Courtenay River Estuary, Courtenay, B.C.

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JUVENILE SALMON SURVEY, 1998, COURTENAY RIVER ESTUARY, COURTENAY, B.C.

by

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ABSTRACT

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Between May 6 and July 29,1998, duplicate beach seine sets were completed at 17 sites within the Courtenay River estuary. Juvenile salmonids captured were counted and identified to species and non-salmonids were also enumerated and identified to common name. Temperature, salinity and dissolved oxygen levels were measured to assess water quality. ANOVA analysis on the physical variables indicated that there were two significantly different regions in the estuary. The upper and lower regions varied as to the level of influence from the Courtenay River as well as the temperature regime. In both regions, the catches of juvenile salmonids in the estuary were lower than other estuaries on the east coast of Vancouver Island, such as in the Campbell River estuary. It is recommended that further studies be carried out to ascertain whether the conditions recorded in 1998 were typical for this estuary.

RÉSUMÉ

Bravender, B. A., L. A. MacDougall, L. R. Russell, C. Beggs and D. Miller. 2002. Juvenile salmon survey, 1998, Courtenay River estuary, Courtenay, B.C. Can. Tech. Rep. Fish. Aquat. Sci. 2395: 63 p.

Entre le 6 mai et le 29 juillet 1998, on a effectué des traits répétés de senne de plage à 17 endroits dans l'estuaire de la rivière Courtenay. Les prises de salmonidés juvéniles ont été dénombrées et identifiées au niveau de l'espèce et les prises d'espèces autres que des salmonidés, dénombrées et identifiées au niveau du nom commun. Une analyse de la variance des variables physiques utilisées pour établir la qualité de l'eau (température, salinité et teneur en oxygène dissous) a révélé la présence de deux régions très dissemblables dans l'estuaire imputable au différent niveau d'influence de la rivière Courtenay sur les régions d'aval et d'amont, à l'origine de régimes de température distincts. Les prises de salmonidés juvéniles dans ces deux régions de l'estuaire étaient moins fortes que dans d'autres estuaires de la côte est de l'île de Vancouver, dont l'estuaire de la rivière Campbell. On recommande que d'autres études soient menées en vue de confirmer que les conditions enregistrées en 1998 sont typiques de cet estuaire.

INTRODUCTION

The Courtenay River is located on the east coast of Vancouver Island, between the cities of Courtenay and Comox (49° 40' latitude, 124° 55' longitude), and flows into an estuary which is also known as Comox Harbour (Fig. 1). Historically this river system has supported natural runs of chinook, coho, chum, pink and sockeye salmon as well as cutthroat and steelhead. In recent years, the numbers of salmonids returning to this system to spawn have undergone a decline. The summer chinook are considered to be endangered and the summer steelhead populations are considered to be at high risk of extinction (Rimmer et al. 1994). These declines have been attributed to a number of factors, ranging from loss of habitat and copper pollution to increased fishing pressure and an increase in the seal population in the estuary (Bigg et al. 1990; Deniseger 1995; Deniseger and Kwong 1996; Campbell 1999).

The cities of Comox, Courtenay and Cumberland rely heavily on the fishing industry for employment . It has been estimated that the fishery provides over 500 jobs for local commercial fishers and the average annual gross revenue for the industry is $24 million. An additional $42.6 million is spent by the industry locally for goods and supplies. Income from the recreational fishery is also important in this area (AGRA Earth and Environmental Ltd. 1996).

In 1997, Fisheries and Oceans Canada began the development of a management plan for the Courtenay River estuary. During the previous two years, the local community had expressed their concern as to the abundance of seals in the estuary, and the subsequent investigations by the department emphasized the need for a management plan to protect and manage the estuary. During the plan development, it became clear that information was lacking on the distribution, abundance and rearing of juvenile salmon within the management plan area, which encompassed the lower Courtenay River and estuary.

To address this issue, a joint field study was begun in 1998 by staff from Fisheries and Oceans, Science Branch, Pacific Biological Station, Nanaimo, and Habitat and Enhancement Branch (Habitat Management, South Coast, Nanaimo and Puntledge River Hatchery, Courtenay). The new information collected was used to develop maps of habitat designations within the estuary as part of the plan development. The data collected during the 1998 study are reported in MacDougall et al. 1999. This report presents an interpretation of the data collected and discusses the results.

WATERSHED

The Courtenay River is relatively short, created by the union of the Puntledge and Tsolum rivers 2.6 km from the confluence with the ocean. Together, these two rivers, along with the Browns River and six other small tributaries, drain a watershed with an area of 859 km^2 (Fig. 2).

Streamflow information is available from seven Water Survey of Canada hydrometric stations within the Courtenay River Water Allocation Plan area. Five of these were still in operation as of 1993: Puntledge River at the Puntledge River power house (08HB006), Tsolum River near Courtenay (08HB011), Browns River near Courtenay (08HB025), Cruickshank River near the mouth (08HB074) and Dove Creek near the mouth (08HB075). Data were available until 1953 for a WSC station on the Puntledge River near Courtenay (08HB007) and a station on Roy Creek only operated in 1971 (08HB042) (Riddell and Bryden 1996). Figure 3 presents the mean flows for the Puntledge River from May 1 to July 31, for the years 1996 to 1998. Mean flows during the same period for the Tsolum River may be found in Figure 4.

Hydrometric station number 08HB006 has recorded information on flows in the Puntledge River for 40 years between 1914 and 1993. During the same time period, a second hydrometric station on the Tsolum River (08HB011), has recorded flow data for 37 years. These data were used to produce Figure 5, (from Riddell and Bryden 1996), to calculate the regulated mean monthly and mean annual discharge and the natural mean monthly and mean annual discharge for the Courtenay River. The regulated flows for the Courtenay River are calculated as the sum of the mean regulated flow for the Puntledge River between 1914 and 1993 and the mean natural flows in the Tsolum River for the same period of time. The regulated mean monthly discharge of the Puntledge River at Courtenay, as controlled by B. C. Hydro, ranges from 22.4 m^3 sec^{-1} in August to 54.9 m^3 sec^{-1} in December (Riddell and Bryden 1996). The flows in the Tsolum River are not controlled and the mean natural flows vary between 0.9 m^3 sec^{-1} in August and 20.7 m^3 sec^{-1} in December. Together, they result in estimated mean regulated flows in the Courtenay River between 23.3 m^3 sec^{-1} in August and 75.6 m^3 sec^{-1} in December. The natural mean monthly and mean annual discharge for the Courtenay River are calculated as the sum of the estimated natural mean monthly and mean annual flows in the Puntledge River and the natural mean monthly and mean annual flows in the Tsolum River. The regulated flows in the Courtenay River mimic the natural flows but are usually higher by as much as 1.5 times in the months of July, August and September and are slightly higher than the natural flows in December. They are marginally lower during the rest of the year (Riddell and Bryden 1996).

The mean total annual precipitation for this area is 1569.6 mm, with a minimum mean monthly precipitation of 35.5 mm in July and a maximum mean monthly precipitation of 291.1 mm in December (Riddell and Bryden 1996).

The largest lake in the watershed is Comox lake, approximately 16.2 km^2 in size, from which the Puntledge River flows. Hydro dams are situated at the outlet of Comox Lake, and 4 km downstream from the lake, on the Puntledge River. Water is carried by a penstock a further 5 km to a powerhouse. Instream flow requirements to mitigate the impact on fish requires minimum flows in the Puntledge River below B. C. Hydro's dam and above the Tsolum River

confluence of 20.5 m^3 sec^{-1}. However, if inflow to Comox Lake is not sufficient, then a minimum flow of 15.6 m^3 sec^{-1} is maintained. Between 1914 and 1993, the desired minimum flow of 20.5 m^3 sec^{-1} was not met in seven out of ten years during the month of August. Flows in the Tsolum River are often below the required 10% of the mean annual discharge as well, especially during the month of August (Riddell and Bryden 1996).

The Tsolum River is 30 km long and drains a watershed with an area of 258 km^2 (Fig. 2). The flow pattern is determined by the mountainous topography, with 71% of the run-off occurring as rain between November and March and only 4% occurring between July and September as the result of snow melt (AGRA Earth and Environmental Ltd. 1996). There are five hydrometric stations in the Tsolum River watershed, two on the river itself and one on each of Dove, Headquarters, and Pyrrhotite creeks. The station on the lower Tsolum River, which records water levels hourly, was installed in 1914 and has recorded data intermittently throughout the intervening years. In 1964, a weir dam was constructed at the outlet of Wolf Lake by Fisheries and Oceans Canada to facilitate water storage and increase flows in the Tsolum River during dry periods. Repairs carried out to this dam in 1998 resulted in increased water retention and increased summer flows. In 1998, the Tsolum River Task Force constructed four index wells at different distances from the river to measure the water table elevation and predict stream flow losses through seepage (Campbell 1999).

During the summer months, flows in both the Puntledge and Tsolum rivers can become low, the result of the combined effect of the low summer precipitation and extensive hydro and agricultural water use. In 1996 there were 166 water licences in place within the Courtenay River Water Allocation Plan area for waterworks, domestic, industrial, power, irrigation, conservation, land improvement and storage purposes. However, water withdrawal by B.C. Hydro to generate power takes 73.9% of the total volume of water used for all the licences combined, while the second largest annual water demand is for conservation for the enhancement of fish and wildlife (15% of the total) (Riddell and Bryden 1996). Historically, the generation of power began with the construction of the first impoundment dam at the mouth of Comox Lake in 1913. At this time, a maximum of 8.5 m^3 s^{-1} was diverted for power generation but this was increased to 28.3 m^3 s^{-1} when the power plant was reconstructed in 1955. At the present time, the maximum diversion is 29.7 m^3 s^{-1} of water from the Puntledge River (Riddell and Bryden 1996).

During 1997 data loggers at three locations within the Tsolum River watershed recorded ambient water temperatures every fifteen minutes from April to October. In 1998, four more sites were added. During low flow periods (June to September) maximum temperatures between 17.4 °C (upper Tsolum River) and 26.2 °C (Wolf Lake) were recorded. Within the Tsolum River, maximum temperatures for the same period ranged from 16.9 °C (middle river) to 24.3 °C

(lower river). Temperatures were higher in 1998, which was a dryer year, than in 1997, which experienced higher precipitation (Campbell 1999).

The policy of the Ministry of Sustainable Resource Management requires that the province be divided into watershed areas and that a water allocation plan be prepared for each watershed. These approved plans then guide future decisions on the granting of any water licences. Such a plan has recently been developed for the Courtenay River watershed, outlining the general hydrology, history, climate, and drainage areas of the watershed. It also discusses flow requirements, water demands, and fish utilization of the creeks and rivers within the watershed (Riddell and Bryden 1996).

HISTORY OF HABITAT DEGRADATION AND LOSS

Estuary

Prentice and Boyd (1988) note that agricultural use of the estuary began when the first white settlers arrived in the area in the 1880's, as is the case for many of the estuaries on the Pacific coast. In 1874, the first major wharf was built in Comox. A road following the shore from present-day Courtenay to the wharf was constructed at the same time, as was the first bridge over the Courtenay River. In 1895 the flat road following the shore was replaced in areas, and reinforced, by the dyke road (Mackie 1995). This road prevented the continued tidal inundation of the salt marshes behind it, which were then converted to agricultural fields which are still largely in use today.

Between 1950 and 1988, approximately 14 hectares of intertidal and subtidal habitat were lost to agriculture, the construction of a lagoon for the treatment of sewage, marinas, housing developments, airport runways and Fields sawmill (Prentice and Boyd 1988; Morris et al. 1979). Today, a portion of Comox Harbour is used for log dumping and sorting, and dredging is required to maintain channels for transportation of logs through the estuary and into the river. Sewage disposal in the estuary, and the resulting faecal coliform contamination, has led to closures of shellfish harvesting in Comox Harbour on numerous occasions and sewage pollution in the estuary continues to be of concern (Morris et al. 1979).

Watershed

The Ministry of Environment, Lands and Parks reported on the water quality of the Tsolum River (Deniseger 1995) and recently the Tsolum River Task Force summarised the available information for the Tsolum River and its watershed in their publication for the Tsolum River Restoration Society (Campbell 1999). This report includes the monitoring carried out by a number of volunteer groups who measured water quality, mapped habitat and undertook restoration at selected sites, including streambank and side channel stabilization,

refuge pond construction and stream channel complexing. In 1996, an investigation into the source and degree of acid mine drainage from the Mt. Washington mine into the Tsolum River watershed was carried out for the provincial Ministry of Environment, Lands and Parks by AGRA Earth and Environmental Ltd.

Historically the Tsolum River and its tributaries have provided habitat for coho, chum and pink salmon as well as anadromous steelhead and resident cutthroat trout. However, alienation and loss of fish habitat started as early as the late 1880's when logging began in the watershed and loggers attempted to float the logs down the river to the estuary. This practice resulted in scouring of the river bed and destruction of streamside habitat. In the 1950's, the Water Survey Branch of Canada attributed the doubling of maximum flows in the lower river, as compared to those recorded in 1916, to increased clear cutting and the loss of forest cover (Campbell 1999). These changes led to increased siltation of salmon redds, lower summer flows and increased water temperatures. Consequently the success of salmon spawning and rearing within the river decreased (Campbell 1999). Loss of spawning gravel also occurred when gravel was removed from the Tsolum River in the 1950's to construct airport runways in Comox (Deniseger 1995).

Between 1964 and 1967, a 13 hectare open pit copper mine was operated on Mount Washington in the upper Tsolum River watershed. After this mine was abandoned in 1967, acid mine drainage continued to leach into the surrounding creeks. In the early 1980's, B.C. Environment established sampling stations on tributaries to the Tsolum River which drained the mine area and documented the increased copper levels. Water quality objectives established by B.C. Environment for the Tsolum River are 11 parts per billion (0.011 mg/l) with a 30 day average of 7 ppb (0.007 mg/l). In 1996, copper levels ranging between 19 and 110 ppb (0.019 and 0.11 mg/l) were measured in the Tsolum River downstream of its confluence with Murex Creek. Even higher levels of between 13 and 17,400 ppb (0.013 and 17.4 mg/l) were measured in Pyrrhotite Creek immediately below the mine (AGRA Earth and Environmental Ltd. 1996). Bioassays carried out at the Puntledge River Hatchery during 1984-85 found that lethal concentrations of copper (LC50) ranged from 23 µg/l for coho smolts to 134 µg/l for pink fry (Hilliar, unpublished data). This study found that copper levels in Murex creek are lethal much of the time while levels in the Tsolum River can be lethal during the spring freshets.

The highest levels of copper are recorded during spring runoff in May and June, as well as during early fall storms. It has been estimated that spring copper loading in Pyrrhotite Creek must be reduced by 95% to meet water quality objectives and to protect aquatic life in the Tsolum River (Deniseger 1995). It is thought that juvenile coho, steelhead and cutthroat are more vulnerable to toxic levels of metals because they reside in freshwater longer than the juveniles of pink and chum salmon and that exposure to these toxic levels reduces the

tolerance of all juvenile salmonids to sea water. Low summer flows are considered to be the second most important factor in the loss of the Tsolum River stocks (AGRA Earth and Environmental Ltd. 1996).

Between 1988 and 1992, attempts at remediation of the mine site included capping of the waste rock with soil and various impervious compounds as well as the construction of new drainage channels to limit the flow of water through the area. Lower levels of copper were recorded in 1998 (1.4 to 2.8 mg/l) as compared to 1986-1989 (3.6 to 7.6 mg/l). However, remediation measures are judged to have been only partially successful and high copper levels are still considered to be adversely impacting all species of salmonids within this river (Campbell 1999). Due to the loss of the salmon stocks which previously flourished in the Tsolum River it has been estimated that the salmon fishery, including steelhead, is losing potential revenues of over $985,000 per year. Projected costs to reduce the levels of acid rock drainage from this mine to an acceptable level are in the range of $2 million to $5 million. Options available include construction of ditches or a grout curtain to divert surface water from the mine area, covering the area with till, mining of the remaining minerals or construction of a tiered wetland to immobilize the sulphides (AGRA Earth and Environmental Ltd. 1996).

Other metals found in the Tsolum River, which are at times above the levels of water quality criteria are aluminium, iron and lead (AGRA Earth and Environmental Ltd. 1996).

SALMONID UTILIZATION AND ENHANCEMENT

Puntledge River

The dam on Comox Lake was first constructed by Canadian Collieries (Dunsmuir) Ltd. in 1913 to provide power to the local coal mines. Between 1955 and 1958, the British Columbia power commission expanded the generation capacity of this facility by raising the elevation of the Comox Dam and the diversion dam on the Puntledge River to increase the diversion of water from 8.5 $m^3 sec^{-1}$ to 27.2 $m^3 sec^{-1}$. The negative results from this undertaking included the flooding of spawning beds historically used by summer chinook and a mortality rate of 30 % to 60% for juvenile salmonids attempting to migrate downstream (Global Fisheries Consultants Ltd. 1992).

In 1965, the Puntledge River spawning channel was constructed below the dam on Comox Lake by B. C. Hydro to compensate for some of the hazards to fish imposed by hydro-electric development on that system (Lister 1968). Several years of poor spawning of chinook in this channel led to temporary hatchery facilities being constructed on-site. This spawning channel was then converted to a rearing channel in 1981 when the Puntledge Hatchery was constructed downstream. Fisheries and Oceans Canada now operates both

sites on the Puntledge River for the production of coho, chum, chinook, and pink salmon, as well as steelhead and cutthroat trout (Riddell and Bryden 1996).

The Puntledge River is stocked with salmon and trout. As well, wild stocks of coho, chum, chinook, pink, steelhead, and cutthroat trout rear in the river. Cutthroat and rainbow trout, Kokanee salmon and Dolly Varden are resident in Comox Lake and it is also stocked with coho salmon fry (Riddell and Bryden 1996).

Escapement data for the Puntledge River between 1953 and 1997 are graphed in Figures 6 and 7 as five year averages. This data shows that the most abundant fish have been chum with an overall mean ± 1SE for this time period of 50,500.0 ± 4,401.1 spawners. For coho, the overall mean ± 1SE for the same time period was 6,790.1 ± 1,003.8.

Pink salmon returning to spawn in the Puntledge River have varied between zero in 1986 to 100,000 in 1997, with the numbers above 15,000 in eleven of the years between 1953 and 1999. Abundances were particularly low between 1964 and 1976. Pink have been the second most abundant salmonid with an overall mean ± 1SE for all years of 12,193.6 ± 2,992.5.

The Puntledge River supports two runs of chinook. Those fish that arrive to spawn between late May and mid August are considered to be summer chinook. Chinook entering the system after mid August are considered to be fall chinook. Summer chinook are generally smaller than the fall chinook and tend to have a more streamlined body. Escapements of summer chinook have varied dramatically, with a high of 5,000 in 1949 and a low of 142 in 1995 (B. Munro, pers. comm.). Between 1949 and 1997,escapements of 500 fish or less were recorded in 24 out of 49 years (49%). Overall mean escapement ± 1SE for this time period was 960.4 ± 150.1. Before the construction of the dam and the flooding of their traditional spawning beds, the summer chinook held in Comox Lake and then moved into the Puntledge River and some of the smaller lake tributaries to spawn in late September and October. In recent years, the summer run chinook have been judged to be in danger of extinction, and in 1998 efforts to control the seal population within the upper estuary and the lower Puntledge River were undertaken to protect both the summer and fall runs of chinook (E. Lochbaum pers. comm.) .

The fall run chinook have also reached dangerously low levels. In 1987, only 40 fall chinook returned to the Puntledge River to spawn (B. Munro, pers. comm.). Escapements between 1949 and 1997 reached a maximum of 6,000 in both 1954 and 1958, with a mean ± 1SE of 1144.8 ± 215.1 for this period. Traditionally, the fall chinook spawned downstream of Stotan Falls. Since the hatchery was constructed in the late 1970's, there has been virtually no fall chinook spawning between the fence across the Puntledge River at the hatchery and Stotan Falls, with the entire run being diverted into the hatchery for brood

stock. A small number of fall chinook spawn naturally below the hatchery fence, but are limited to only two small sites due to the lack of suitable gravel (B. Munro, pers. comm.).

Sockeye have occasionally been seen spawning in the Puntledge River, but they are sporadic with a maximum of only 435 fish in 1968. Sockeye are not native to this watershed but were introduced in past years and are released to spawn naturally if captured along with other brood stock for the Puntledge River Hatchery.

Low flow problems in the Puntledge River have historically caused severe salmon mortalities, as juveniles perished in the hydro generating turbines, and fluctuations in water flow impaired adults at Stotan and Nib falls. Since these problems were first identified, changes were made to the turbines to protect juveniles, flows were stabilized and baffles were constructed at Stotan and Nib falls. Additional modifications of the turbine intakes were undertaken in 1989 to further reduce the mortality rates of juvenile salmonids, which ranged from 30% to 60% (Lister 1968). High temperatures are problematic in the Puntledge River as well and have negative effects on fish reared at the Puntledge River Hatchery.

Tsolum River

Historically, the Tsolum River was an important producer of coho, pink and chum salmon as well as steelhead and anadromous cutthroat trout (Campbell 1999). In the 1950's, the annual escapement of coho was approximately 10,000 fish. This dropped to zero in 1994 (Fig. 8). Runs of odd and even year pink salmon were as high as 100,000 in the late 1940's and 1950's. Enhancement of the pink populations was begun in the late 1960's and has continued sporadically until recently. However, despite efforts to boost these runs, returns dropped to zero for the even year runs in 1986 and increased to only 200 in 1994. The odd year run pinks declined to 300 in 1987, rebounded to 20,000 in 1991 and again dropped sharply to only 100 in 1995 (Fig. 9) (Hilliar, unpublished data). In 1967 there were 436 steelhead anglers on the Tsolum River, who kept 393 wild steelhead. By 1980, this had dropped to 3 anglers, who caught and released 36 wild steelhead (Campbell 1999). In 1998, the summer steelhead escapement was less than ten.

Enhancement initiatives in the Tsolum River by Fisheries and Oceans Canada began in 1964 and included the construction of the Wolf Lake weir to increase water storage and flows during the summer months and the start of a hatchery research program at Headquarters Creek. The low summer flows continued to be a problem and in 1976, an investigation was carried out to determine the costs of increasing flows to accommodate the construction of various structures, ranging from incubation boxes to a 6.3 meter long spawning channel. It was determined that the cost would range from $0.76 M to $1.5 M.

Recently, the continued problems from low flows and elevated copper levels have led to a proposal to divert water from the Puntledge River to meet the irrigation demands on the Tsolum River, thus reducing the withdrawal of water from this river (AGRA Earth and Environmental Ltd. 1996).

B. C. Environment only became aware of water quality problems in the Tsolum watershed in the 1980's, when sampling stations were established on tributaries to the Tsolum River that drained the area where the copper mine was located. Since then, continued monitoring has shown that degraded water quality has been a factor that has severely limited the success of restoration efforts undertaken by numerous agencies (AGRA Earth and Environmental Ltd. 1996). Between 1968 and 1999 juvenile salmonids were released into the Tsolum River watershed. This included juvenile chinook from the Big Qualicum River (1969), juvenile pink from the Quinsam River (1994, 1995 and 1999), and juvenile pink, coho, steelhead, anadromous cutthroat and chum from the Puntledge River. Releases of adults from the Puntledge River into the Tsolum River included adult pinks from 1987 to 1990 and 1996 to 1997 as well as adult chums in 1998 (Campbell 1999). In 1982, 1983, 1993 and 1994, there were poor returns of pink despite these efforts. The agencies involved in this included Fisheries and Oceans Canada, the B. C. Fish and Wildlife Branch and the B. C. Ministry of the Environment.

These enhancement initiatives have met with limited success and efforts have become more focused on the problems of poor water quality, including high temperatures, and pollution from the copper mine. Recommendations from the Tsolum River Task Force include the construction of silt settling ponds, monitoring of water quality and flow, continued assessment of offstream ponds and refuges and improvement of bank stability and riparian strips. Investigations into the apparent relationship between stream flows and increased escapement numbers as well as the possibility of transplanting stock from other warm water systems, such as the Glendale River system in Knight Inlet, to the Tsolum watershed have also been recommended (Campbell 1999).

Courtenay area

Other freshwater tributaries in the area are also important to salmonids, at both juvenile and adult stages. Coho, chum and cutthroat have been identified in Roy Creek. Steelhead and cutthroat trout reside in Millard Creek, and coho, pink and chum salmon use Millard Creek for spawning and rearing. Perseverance Creek is stocked with coho, and Morrison Creek is used by steelhead and cutthroat trout, as well as coho and pink salmon (Riddell and Bryden 1996). The Trent River is also stocked with coho salmon, and coho and chum have been recorded migrating up-river (Brooks et al. 1994).

Since 1972, as part of the Salmonid Enhancement Program, Fisheries and Oceans Canada has released juvenile coho, chinook (summer and fall), chum,

pink, cutthroat and steelhead (summer and winter) into the Courtenay River estuary and many of the lakes, creeks and rivers in the Courtenay area. These fish included stocks from the Puntledge, Quinsam, Big Qualicum, Trent and Little Qualicum rivers as well as stocks from Millard and Roy creeks. Release sites included the Trent, Puntledge and Cruickshank rivers, as well as Roy, Millard, Guthrie, Hobson, Portugese, Dove, Eric, Morrison, Rees, Brooklyn, Finlay, Headquarters and Bloedel creeks. Some juveniles were released into Comox and Bradley lakes high in the watershed as well as into Comox Bay (Comox Harbour in Fig. 1). Some fry were held and fed before release while others were allowed to emerge and migrate at will. Small numbers of coho juveniles were reared in school classrooms and released to local creeks. As well, crossing several stocks to increase survival was undertaken with pink (Quinsam River x Puntledge River), and fall chinook (Big Qualicum River x Little Qualicum River) juveniles (G. Bonnell, pers. comm.).

The juvenile salmon released into the Courtenay area between 1989 and 1998 and the totals for these ten years are listed in Table 1 and graphed in Figures 10 and 11. Between 1989 and 1998, the mean number of summer chinook released ± 1SE was 730,622.5 ± 190,784.1, with annual releases varying from 176,985 in 1997 to a high of 1.9 million in 1989. Releases of fall chinook during this same time period have ranged between a maximum of 3.6 million in 1990 to a low of approximately half a million in 1994, with a mean ± 1SE of 1,755,244.9 ± 351,122.2. The number of chum juveniles released varied from a low of 2.8 million in 1990 to a maximum of 5.8 million in 1998 with a mean release during this period of 4,445,670.5 ± 301,684.1 fish. Juvenile pinks peaked in 1989 at 3.3 million, while the lowest release of 1.3 million was in 1990 (mean of 2,394,286.6 ± 137,399.0). Coho juveniles declined from a high of 2.3 million in 1990 to a low of half a million in 1993, with the mean number released during this period ± 1SE of 1,642,498.7 ± 178,820.9.

The Puntledge River hatchery also releases summer and winter run steelhead with a high for summer fish of 94,731 in 1994 and a low of 9,731 in 1995 (Fig.12). The mean release of summer run steelhead for this period was 46,252.7 ± 8,638.9. Releases of winter steelhead have undergone a dramatic decline during this period, from 76,888 in 1991 to 0 in 1997 (mean of 34,022.8 ± 7,731.0). The numbers of cutthroat produced have varied between a maximum of 13,524 in 1993 and a minimum of 0 in both 1992 and 1997 with a mean for this period of 4,129.6 ± 1,523.0. Total annual releases of juvenile salmonids between 1989 and 1998 varied from a maximum of 15,025,696 in 1991 to a minimum of 8,318,943 in 1997. During these ten years, 110.5 million juvenile salmonids were released into the Courtenay area and estuary with an annual mean total of 11,052,728.3 ± 652,843.4 (G. Bonnell, pers. comm.)(Table 1).

During 1998 a total of 10,505,661 juvenile salmon were released into the Courtenay area (Table 2). Chum juveniles, all fed fry reared in fresh water (Fed FW), comprised 54.9% (5.8 million) of the total (Fig. 13). Pink were next in

importance at 20.7% (2.2 million) of the fish released, and included fed fry reared in salt water (Seapen) and unfed fry (Unfed). Coho released included both fed fry released in spring (Fed Spr) and smolts (Smolts). The 1.1 million coho juveniles made up 10.5% of the releases during 1998. A total of 0.97 million (9.2%) fall chinook were released with summer chinook comprising 3.9% (0.4 million) of the releases. Releases of chinook included both subyearling smolts (Smolt 0+) and subyearling smolts reared in salt water (Seapen 0+). The releases of juvenile trout were dominated by winter steelhead (53.4%)(48,772) followed by summer steelhead, which made up 45.5% (41,575) of the total. These were juveniles with one year of freshwater rearing (winter run = Sm Wr 1+) (summer run = Sm Sr 1+). Cutthroat trout, comprised of smolts with 1 year in freshwater (Smolt 1+), made up 1.1% (1,064) of the total trout production (Fig. 14) (G. Bonnell, pers. comm.).

During 1998, yearling chinook smolts raised in fresh water (764,750 fall and 253,921 summer chinook) were between 84.4 and 86.1 mm mean length and weighed between 6.1 and 6.9 grams when released June 2-7 (Table 2). As well, 196,924 fall and 152,092 summer chinook smolts were held in seapens in Comox Bay for several weeks prior to their release on June 4. At this time, the fall chinook averaged 87.0 mm mean length and 7.0 grams mean weight while the summer chinook averaged 82.0 mm mean length and 6.1 grams mean weight. The 5.8 million chum, held in fresh water and fed, were released between April 2 and May 7, at which time they were 55 mm mean length and weighed between 0.5 and 1.2 grams mean weight. Coho released were of different stages. This included 414,404 fry that were held in freshwater, fed and then released during May and June when they varied from 66.4 to 71.8 mean length and weighed an average of between 1.5 and 4.4 grams. A total of 297,273 of these coho fry were released to colonize Comox Lake, Cruikshank River, and Eric and Rees creeks. In addition, 686,773 larger coho smolts (121.3-129.4 mm, 18.2-22.9 g) were also released between May 11 and May 19. Pink smolts (1,498,647) reared for several weeks in seapens in Comox Bay, reached 54.9 mm mean length and 1.6 grams mean weight prior to their release on April 21. A total of 677,291 unfed pink fry (31.9 mm mean length, 0.21 grams mean weight) were also released into the Puntledge River between January 5 and April 6. Steelhead smolts, all yearlings, varied from summer stock with mean lengths of 187.8 mm and mean weights of 61.3 grams to a mean length of 195 mm and mean weight of 85.0 grams for the winter fish released. They were released into the Puntledge River between May 7 and 12. Yearling cutthroat smolts were of similar mean size (195.0 mm) and weight (80.8 g) to the steelhead when they were released to the Puntledge River on May 12.

During 1998 juveniles of all species except pink were tagged with coded wire tags (Table 2). Low numbers of chinook (summer and fall), chum and coho were also adipose clipped only. Fish marked with CWT's made up between 1.2% (chum) and 100% (cutthroat, summer and winter steelhead) of the releases.

THE COURTENAY RIVER ESTUARY

The Courtenay River drains into a shallow estuary, 1345 ha in area, and comprised of a mosaic of sand, gravel, mudflats and eelgrass beds. Additional inflows of fresh water to the estuary are supplied by the Millard, Roy and Brooklyn creeks as well as the Trent River (Fig. 1). The estuary is stratified, consisting of a saltwater wedge below a surface layer of fresh water. Salinities in the estuary can be as low as 0 $^{o}/_{oo}$ or as high as 29 $^{o}/_{oo}$, depending on whether the tide is ebbing or flooding. Tides in the area are typically diurnal and mixed, with a large tidal range. Oceanographic surveys of the estuary in 1958 showed depths up to 27 metres at one site in the outer one third of the estuary (Morris et al. 1979). Wind mixing in the estuary is minimal, due to protection provided by Denman and Hornby islands, and Goose Spit. Currents are moderate, between 1 to 2 knots, even at depth, as are wind and wave effects (Morris et al. 1979). Because the estuary is shallow, water temperatures can be very high in the summer. The estuary is connected at the mouth to a shallow body of water, (Baynes Sound) which encompasses the area between Denman and Vancouver islands.

The Courtenay River has been dredged and confined to a channel situated on the north-east side of the estuary, providing a navigable passage through the estuary to the river. Currents in the river are swift at times, depending on tide and discharge rate from the dam on Comox Lake. The banks of the river are sandy and gradually sloping in the lower portions of the channel, and sandy, steep and covered in marshgrass in the upper portions of the channel. The riparian zone in the upper channel stretches to the high water mark in some areas, with trees and shrubs extending over the water. The lower channel has a large sandy intertidal area, with a riparian area set back from the channel.

In 1975, the Nature Trust of British Columbia purchased approximately nine acres of property to the east of the dyke road, consisting of mostly tidal slough with an area of mudflat and riparian upland. A weir connects this property to the estuary and it has been leased to the Comox-Strathcona Natural History Society for 99 years. This area supports wildlife as well as waterfowl and juvenile coho salmon. In 1998, Ducks Unlimited, acting for the Pacific Estuary Conservation Program, announced the purchase of a 192 acre farm adjacent to the shoreline of the estuary. The long term plans are to keep this area as farmland.

In September, 1997, Fisheries and Oceans Canada initiated a multi-stakeholder process to develop an Estuary Management Plan for the Courtenay River estuary. This plan will designate types of appropriate activities within the estuary, establish a co-ordinated project review board to address specific proposals within the management plan area, and promote consistency,

transparency and public participation in the development and implementation of the plan. This plan will also ensure that a common, long term vision of wildlife and habitat conservation is maintained.

PREVIOUS STUDIES

The eighth volume of the Fisheries and Environment Canada special estuary series summarized the information available for the Courtenay River estuary up to 1978 (Morris et al. 1979). This study was undertaken by the Estuary Working Group, comprised of representatives from federal and provincial agencies. The report documents the historical, geological, oceanographic and biological information available for the estuary, and includes sections on land use, water quality, pollution and the effects of development.

Recently, the estuary and the adjoining Sound have become the focus of interest for a number of community action groups, including the Baynes Sound Round Table which was formed in 1994 to deal with declining water quality. This group brings together government, industry, local politicians and environmental groups and has undertaken a number of initiatives, including Sound stewardship groups, hot spot monitors and adopt-a-stream neighbourhoods (Caine 1997). Pollution concerns stem largely from the run-off of sewage from septic fields into the streams and rivers feeding into the estuary and the overflow of sewage from a local disposal system. The high faecal coliform counts resulting from this have led to extensive shellfish harvesting closures, especially around the mouth of the Trent River (Comox Valley Environmental Council 1991).

Other community groups include watershed and streamkeeper stewards for the Puntledge and Tsolum rivers as well as a number of smaller waterways in the area including Portuguese, Roy, Morrison, Millard, Piercy, Headquarters, Brooklyn, Finley and Dove creeks. These groups have developed watershed plans for many of these areas which include monitoring of water quality, assessment of stream habitat, planting of new riparian zones and mapping of sensitive areas. The Comox Valley Watershed Assembly was formed with the purpose of resolving water-related problems so that the water, watershed and affected marine areas of the Comox Valley may be used sustainably. Teams have been set up through this group to deal with the acid mine drainage from the Mount Washington copper mine and assess the effects of logging on riparian zones along streams within the watershed (AGRA Earth and Environmental Ltd. 1996).

A study of the Trent River was conducted by the Comox Naturalist Society, for the Canadian Wildlife service. This study documented the utilization of the small Trent River estuary by various species of birds, fish, plants and invertebrates, and called for further monitoring of this system (Brooks et al. 1994).

Other studies include oceanographic studies of Baynes Sound and Comox Harbour (Waldichuk et al. 1968; Waldie 1951), an account of historical changes to intertidal and upland habitat in the estuary (Prentice and Boyd 1988), and observations of seal and sea lion predation in the estuary (Bigg et al. 1990). The intertidal fish habitat in the Courtenay River estuary and Baynes Sound is summarized in a prototype fish habitat atlas (Tamasi et al. 1997).

In early May, 1998, this study was begun to augment the technical information available for the development of this management plan. A total of seventeen sites within the Courtenay River estuary were sampled to assess physical variables and the fish fauna present. Seven trips were completed between May 6 and July 29, 1998 (Fig 1)(Table 3).

METHODS

Sampling methods used for this survey are outlined in detail in MacDougall et al. 1999. Briefly, each site was sampled with a beach seine 13.5 m long and 2.9 m deep. The net was pulled offshore to the full 15 m length of the rope bridles by boat where possible, set in a semi-circle back to shore, and retrieved by hand.

Duplicate sets were done at most sites and the entire catch was counted and identified to species. Where necessary, the catch was subsampled with a dipnet, then multiplied by the number of dipnets required to empty the seine, to estimate total catch. Coho and chinook were further identified as marked or unmarked. All or a subsample of salmonids were anaesthetized with Alka Seltzer™ on shore at the site. Fork lengths to the nearest mm and weights to the nearest 0.1 g were recorded. The fish were placed in a bucket to recover and then released back into the estuary at the site of capture once they had recovered from the anaesthetic.

At each site, a YSI Model 33 salinometer was used to record temperature (°C) and salinity (‰) at the surface and at one metre intervals, either to the bottom or a maximum depth of 5 metres. An Oxyguard Handy MK 1 meter and a YSI Model 57 Oxygen meter measured the dissolved oxygen levels in mg/l ± 2%.

Temperature ranges were recorded every 15 minutes at various locations within the lower Courtenay River and estuary with Onset Corporation Stowaway Tidbit Data Loggers. Most were located in areas where they remained largely submerged and data was recorded from early spring to late fall.

Condition factors for the juvenile salmonids were determined by using the equation:

$$K = \frac{W}{L^3} \times 10^5$$

where K is the condition factor, W is the wet weight of the fish in grams, and L is the fork length of the fish in millimeters (Meehan and Miller 1978).

Analysis of variance tests were carried out using Microsoft Excel. Lotus Freelance was used to prepare the graphs in the report.

RESULTS

WATER PROPERTIES

Table 4 outlines the ranges and mean values ± 1SE for salinity, temperature and dissolved oxygen measurements obtained at each site. Based on the physical variables recorded during the study, it was hypothesized that the habitat in the upper estuary offered rearing conditions which were different from those in the lower estuary. Analysis of variance of all the salinity data recorded at all the sites showed these two regions to be statistically significantly different (Table 5). The upper region included sites 1, 10, 11, 12, 13, 14, 16 and 17 while the lower region included sites 2, 3, 4, 5, 6, 7, 8, 9 and 15 (Fig. 1). Surface salinities as well as all salinities to depth recorded were significantly different between the two regions ($P<0.01$), as were the surface temperatures ($P<0.05$). There was no significant difference between all the temperatures recorded at each site between the two regions, nor was there a significant difference for the dissolved oxygen levels recorded in the two regions.

Temperatures were recorded from depths ranging from 0 m to 3 m below the surface. Over half (53%) of those recorded during the survey were between 16 °C and 20 °C, with a minimum of 12.0 °C (sites 1 and 13) and a maximum of 24.8 °C (site 8). Temperatures of 20 °C or higher made up 34.7% of the measurements and occurred at all sites except stations 7, 13 and 16. Although temperatures were taken from a range of depths, deeper temperatures rarely varied more than two degrees from the surface temperature at any given site.

Surface temperatures recorded during seining in the upper estuary and river channel areas showed a warming trend from late May to late July and fell within the same range as temperatures obtained from data loggers at the 17th Street bridge, Puntledge River Hatchery and lower Tsolum River locations (Fig. 15 and 16). The mean surface temperatures ± 1SE for the two regions of the estuary are graphed by sampling date in Fig. 15. This graph indicates that there was an overlap in these values for the two regions during two of the six sampling trips (May 21 and July 14-15). On the rest of the sampling trips, the temperatures were significantly different from one another. The largest difference was evident during the June 3-4 sampling trip when the lower estuary was significantly warmer than the upper estuary. The information from the data loggers covers a longer sampling period, and illustrates a warming trend that began in May, and continued until mid-August. During this period, temperatures

climbed from 10 ° C to over 20 ° C, and decreased more slowly, to 15 ° C by October.

Temperatures in the upper estuary ranged between 12.0 and 23.5 ° C, with a mean ± 1SE of 18.1 ± 0.4 ° C (Table 4). The lower estuary was slightly warmer with a mean of 19.1 ± 0.4 ° C and a range of 12.3 to 24.8 ° C. The overall mean temperature for all sites in the estuary was 18.6 ± 0.3 ° C.

Salinities in the estuary reflected the effect of the flows from the Courtenay River. Sites in the upper estuary, where freshwater influence was most prevalent, had minimum salinities of 0 ‰ with a maximum salinity of 20 ‰, recorded at site 10 during a flood tide. However, the salinities in this region were typically low and the overall mean ± 1SE was 1.1 ± 0.4 ‰ (Table 4). Salinities were most variable in the lower region, ranging from a minimum of 7.3 ‰ to a maximum of 29.2 ‰, with a mean salinity ± 1SE of 19.3 ± 0.6 ‰. For the estuary as a whole, the mean salinity ± 1SE was 10.5 ± 0.9 ‰.

Dissolved oxygen levels were less variable than temperatures or salinities. Values ranged from 5.4 mg/l (site 14) to 10.7 mg/l (site 13). Dissolved oxygen levels were similar between the two regions as well, with a mean ± 1SE of 8.6 ± 0.2 mg/l in the upper region of the estuary and 8.5 ± 0.2 in the lower region. The mean ± 1SE for all sites combined was 8.5 ± 0.1 mg/l (Table 4).

FISH SURVEYS

Summaries of salmonid catches and CPUE by species and for the two regions of the estuary can be found in Table 6. Seventy-six beach seine sets were done in the upper estuary and 100 in the lower region, capturing a total of 734 juvenile salmonids. By region, the CPUEs ranged from 3.97 for chinook in the upper estuary to 0.01 for cutthroat in the lower estuary. The highest CPUE for all salmonids combined was 7.47 in the upper estuary. Far fewer salmonids were captured in the lower estuary, where the overall CPUE was only 1.66. For both regions combined, the CPUE was 4.17. Of the total salmon captured, 568 (77.4%) were found at sites in the upper estuary while only 166 (22.6 %) were captured in the lower estuary.

Chinook were the most abundant salmonid captured and made up 47.4% of the catch for both regions combined, while 26.0% of the total was comprised of coho (Table 7). In the upper estuary, chinook were the most numerous salmonid captured, comprising 53.2% of the total catch for this region, followed by coho (21.8%) and chum (20.1%). The coho caught in this area were largely fry as were the chinook. The lower estuary was dominated by larger coho smolts (40.4%), followed by chum (28.9%) and chinook smolts (27.7%). In the upper estuary, steelhead (total 21) and cutthroat (total 7) were both captured only at sites 10, 11, 12 and 17 (Fig. 1). In the lower estuary, steelhead (total 4) were

captured at sites 6 and 15, while the single cutthroat captured was found at site 6.

One way analysis of variance (ANOVA) was used to determine the significance of region on the catches of coho, chinook, chum and steelhead (Table 8). There was a significant difference ($P<0.01$) between catches in the upper and lower estuary for chinook as well as for all salmonids combined. Significance between the two regions for steelhead was slightly lower at $P<0.05$. There was no significant difference in the catches of either chum or coho in the two regions of the estuary.

Salmon were more plentiful during the first two sampling trips (May 6 and May 20 and 21) than they were later in the survey (Fig. 17). In the first two sampling trips combined, nearly 49% (356) of the total salmonid catch was recorded. The overall catch was dominated by chum salmon (160), followed by coho (154) and chinook (135). Coho fry were most abundant in the upper estuary between May 6 and June 4, after which their numbers dropped off sharply. The coho smolts were also most abundant during this time but occurred largely in the lower estuary region. Chinook occurred predominately in the upper estuary at several of the river sites between May 6 and June 29.

Patterns in the distribution of the various juvenile salmonids began to emerge during the project. Analysis of the catches by site for the upper estuary showed the highest catches of juvenile salmonids at four sites - 1, 11, 14 and 17 (Fig. 1). Site 17 is the site highest on the Courtenay River, located at the outer bend of the river across from Lewis Park. Site 1 is downstream at the juncture of a small slough and the Courtenay River. This site is characterized by swift river currents and the formation of eddies where the slough and the river join. Site 14 is located inside a pocket off the main river channel which appeared to have been dredged for the moorage of small boats. Site 11 is also off the main river channel in an area where run- off from Duck Slough joins the Courtenay River. Sites 1 and 17 are freshwater dominated whereas sites 11 and 14 are influenced by the incoming wedge of salt water at high tide. Chinook of both hatchery and wild origin were found most frequently at site 17 (CPUE = 15.7), site 14 (CPUE = 10.8) and site 1 (CPUE = 4.0) (Fig. 19). Coho fry were also most numerous at site 14 where the CPUE was 7.7 followed by site 11, with a CPUE of 2.3. Chum fry preferred site 14, where 94 were captured (CPUE = 10.4) (Fig. 19). Low numbers of cutthroat and steelhead were also found in the upper estuary, predominately at sites 10, 11, 12 and 17.

The catch of juvenile salmonids in the lower estuary consisted of mainly coho and chinook smolts. The total catch for all salmonids was the highest at site 9, located at the head of a blind bay next to the Comox Marina (Fig. 1). Here the catch was dominated by coho (CPUE = 4.2)(Fig. 20). At site 8, located in the south-eastern corner of the Comox Marina, chum were captured in the highest numbers (CPUE = 2.7), followed by chinook (CPUE = 1.4). Only a few coho

were found at this site. Because site 8 is located in an area that is dredged, the water depth usually exceeded 3 metres at the time of sampling, even at low tide. This may have been a factor in attracting juvenile salmonids into the area. Site 9 is in the vicinity of an eelgrass bed which may partially account for the higher catches in this area. A few steelhead and cutthroat were also captured in the lower estuary in the area of Goose Spit at sites 6 and 15.

Mean lengths, weights, and K-factors ± 1 SE for each species by site and region can be found in Table 9. Lengths, weights and K-factors were determined for a total of 162 juvenile salmonids. Measurements were taken from 118 chinook, including 77 unmarked of unknown origin, 4 marked hatchery and 37 hatchery chinook. Lengths and weights were also recorded for 43 coho and one chum salmon. K-factor values were between 0.68 (coho fry at site 11 on June 3) and 1.38 (coho fry at site 14, June 4), and only 9.3% of fish measured had K-factors below 0.90. Mean K-factor values were very similar between the two regions, with a mean ± 1 SE of 1.02± 0.01 in the upper estuary and 1.03±0.01 in the lower estuary. The mean K-factor for all salmon from both regions was 1.02±0.01.

One way ANOVA analysis of the lengths, weights and condition factors showed that there was no significant difference for any of these factors between the upper and lower regions of the estuary for chinook (Table 10). This was also the case for all salmon in both regions of the estuary. However, in the upper estuary, the lengths and weights of the chinook vs. those of the coho were significantly different ($P<0.01$). Although rearing conditions appeared to be similar in both regions the coho captured in the upper estuary were largely small wild fry whereas the chinook catches in this area were dominated by larger hatchery juveniles.

A total of 9053 non-salmonids were captured during the study, 2941 in the upper region and 6112 in the lower region. Overall, sculpins dominated the catches and were more abundant in the lower estuary (CPUE=24.9), than in the upper estuary (CPUE =11.6)(Table 11). In the upper estuary, the highest CPUE for sculpins was 26.5 at site 10, followed by site 14 (CPUE=24.8). In the lower estuary sculpins occurred in the greatest numbers at site 6 (CPUE= 42.5), site 3 (CPUE=39.2) and site 8 (CPUE=35.8). The largest single catches of sculpins were made during the May 21 sampling trip when 372 were captured in two sets at site 8 and another 309 were also caught in two more sets at site 9 (Fig.18). However, they were present at every site sampled, often in very high numbers. For all catches combined, sculpins comprised 37.2% of the total catch of non-salmonids (Table 12). The results of one way ANOVA of the distribution of non-salmonids in the upper and lower region of the estuary showed that the difference in the distribution of sculpins between the upper and lower estuary was statistically significant ($P<0.01$) (Table 13).

Sticklebacks (*Gasterosteus aculeatus*) were only slightly more abundant in the upper estuary, with a CPUE of 18.7, compared to the lower region where the CPUE was 15.3 (Table 11). Sticklebacks made up 32.6% of the total catch of non-salmonids in both regions of the estuary combined (Table 12). Large schools of sandlance (*Ammodytes hexapterus*) were captured in the lower estuary only (CPUE=9.0) (Table 11). Perch (Family Embiotocidae) were next in abundance with a CPUE of 5.2 in the lower estuary, 4.4 in the upper estuary and 4.9 for all samples (Table 11). They made up 9.5% of the total non-salmonid catch (Table12) (Fig. 18). Flatfish captured included speckled sanddabs (*Citarichthys stigmaeus*), starry flounders (*Platichthys stellatus*) and other juvenile flatfish that were not identified. The CPUE of 4.8 in the lower estuary for all flatfish combined was higher than the CPUE for this group in the upper estuary of 3.7 (Table 11). Flatfish formed 8.4% of the total non salmonid catch (Table 12). One way ANOVA analysis showed that the difference in the distribution of stickleback, perch and flatfish in the upper and lower estuary was not statistically significant (Table 13). Gunnels, including saddleback (*Pholis ornata*), penpoint (*Apodichthys flavidus*), and unidentified juveniles, unidentified blennies (Family Stichaeidae), Pacific snake pricklebacks (*Lumpenus sagitta*) and white spotted greenlings (*Hexagrammos stelleri*) as well as unidentified adult and juvenile greenlings were also much more abundant in the lower region of the estuary (Table 11).

DISCUSSION

Our analysis has shown that in 1998 the Courtenay River estuary provided two significantly different habitat types for the rearing of juvenile salmonids in the system. These were the upper region, including the lower Courtenay River and upper north-east corner of the estuary and the lower region, which included the remainder of the eastern shore and most of the west side of the estuary.

Measurements of salinity taken during this study indicated that the upper region of the estuary was influenced by the flow from the river to a much greater extent than the lower region. Frequently there was no detectable salinity at all in the upper area, even to several metres depth, especially at the river sites. Coho fry as well as chinook fry and smolts were captured in the highest numbers in this region. During our sampling these juveniles were often found in off channel areas, many of which are man made and offer shelter from the high currents typical of the main river channel (Fig. 19, 20). Such areas included dredged pockets (site 14) and sloughs (site 1) as well as flooded marshes (site 11). Surface water temperatures in this region were often less than the temperatures recorded at sites in the lower region of the estuary. During four of the six sampling trips, the temperatures were significantly higher in the lower region of the estuary when compared to the upper region (Fig. 15).

The lower region of the estuary is predominately mudflat which is exposed at low tide. This area absorbs and holds heat during hot summer days and in turn warms the incoming water during the flood tides. In addition, the river has been dredged to facilitate navigation and this has resulted in the flow being largely confined to a narrow channel on the north-east side of the estuary. This has the effect of restricting the influence of the freshwater runoff on the western region, even during high tide. Consequently, the highest salinity recorded during the study was at site 5 (29.2‰) on the western shore of the estuary.

Some of the highest temperatures recorded during the project were also in the western region of the estuary. Due to the higher elevation and shallow slope, this region is covered by the tide for the least amount of time and the water is often less than a metre deep except at the extreme high tides. These factors combined result in habitat which is not suitable for juvenile salmonids and this was reflected in the poor catches of juvenile salmon on the mid and upper west side of the estuary during 1998 (e.g. at sites 3, 4, and 5) (Fig. 19, 20). Walthers and Nener (1997) suggest that temperatures between 16°C and 21°C may be detrimental to salmonids. They suggest an upper lethal temperature of 25 °C range for anadromous Pacific salmon and a lower lethal temperature range of 21°C . Experiments carried out by Brett (1952) determined the preferred temperature range for juvenile Pacific salmon to be between 12 °C and 14 °C. As mentioned earlier, over half of the temperatures recorded during this study were between 16 °C and 20 °C. These temperatures are likely high enough to increase the stress levels in the juvenile salmon and to negatively affect feeding, growth and their resistance to disease. Nonetheless, most of the fish captured were in good condition with condition factors approaching or exceeding 1.0. The notable exception was the coho fry previously mentioned that was captured at site 11 in early June.

The timing of salmonid abundance in the Courtenay River estuary in 1998 was similar to that reported by Levings et al. (1986) for chinook in the Campbell River estuary, and by Healey (1979) for the Nanaimo River estuary. Levings et al. (1986) found that chinook abundances decreased markedly in June, while Healey (1979) determined that chinook reside in estuaries until late June or July. Our results indicate that overall abundances of salmonids decreased dramatically after the June 6 and 7 sampling, with the exception of chinook abundances, which remained slightly higher until the end of June.

As previously mentioned, the numbers of sculpins were significantly higher in the lower estuary, where the largest single catches of sculpins were made at sites 8 and 9. Numerous species of sculpin were captured, but the catches appeared to be dominated at most sites by staghorn sculpins (*Leptocottus armatus*). This species of sculpin has been documented as a predator on juvenile chum salmon fry (*Oncorhynchus keta*) in an estuarine environment (Mace 1983). Research has also shown that sculpins not only predate on juvenile salmonids and compete with them for rearing space, in some cases they

consume the same prey items and may thus have an adverse impact on their growth and survival. In a study in a Norwegian river, Gabler and Amundsen (1999) documented interspecific competition for limited food resources between a Siberian sculpin (*Cottus poecilopus*) and Atlantic salmon parr and suggested that this may have resulted in low production of Atlantic salmon in this river. An experimental study of the sculpin and coho populations of Carnation Creek found an overlap in food preferences and feeding, as well, which resulted in reduced growth rates for the coho, although the author concluded that this might not be the case in a natural system (Ringstad 1974).

While it is not known whether the large numbers of sculpins in the Courtenay River estuary are impacting the juvenile salmonid populations in a significant manner, their presence at the very least indicates habitat that is generally warmer than the type of habitat that is optimal for rearing salmonid juveniles.

The low catches of juvenile salmonids during this survey indicated that few juvenile salmon of either wild or hatchery origin remained in the area to rear, with the majority appearing to migrate into other regions. Releases of juvenile salmonids into the Courtenay River watershed and Comox Bay just prior to or during this survey included 1.4 million summer and fall chinook (June 2-7), 5.8 million chum (April 2-May 7), 1.1 million coho (May and June), over 1,000 cutthroat trout (May 12) and 90,000 summer and winter steelhead (May 7-12). Of the 1.1 million coho released, approximately 400,000 were coho fry which would be expected to remain in the upper watershed until the following spring. The remainder were released into the Puntledge River and Comox Harbour. Despite this, a total of only 734 juvenile salmonids of all species were captured in the Courtenay River and its estuary during this project and many of these juveniles appeared to be of wild origin.

SUMMARY

Development on the Courtenay River estuary and within the watershed has altered the levels of habitat diversity. Impacts from forest clearing, agricultural water use and runoff, and the construction of residential areas can adversely affect fish and fish habitat. While Childers and Gosselink (1990) assert that forested streambanks filter phosphorous, nitrogen, and sediments from runoff waters, agricultural and urban areas are large sources of such nutrients, as well as suspended sediments. The introduction of nutrients and sediments can alter water quality, damage streamside vegetation, and change substrate levels, thereby negatively affecting aquatic populations.

The accumulation of effects needs to be considered on both spatial and temporal scales. McCold and Saulsbury (1996) suggest a need to include historical changes when assessing cumulative impacts. They also suggest that the most appropriate baseline for comparison is the state of the habitat or

resource at its most productive or least affected by humans. While in our study it may be difficult to assess which sites within the estuary are most or least productive, it is apparent that the numbers of juvenile coho, chinook and pink currently within the system are lower than historical levels.

The copper pollution originating from the Mount Washington mine has been judged to be the primary cause of the decline and subsequent loss of the once abundant runs of salmonids in the Tsolum River (AGRA Earth and Environmental Ltd. 1996). Efforts are still ongoing to reduce the copper levels in the Tsolum River and return the river to its former levels of productivity. Research has shown that, although copper has been transported downstream as much as 18 km from the mine site, it has become stable, bound in the sediments of the lower watershed. It is postulated that the water quality in the river will be acceptable if there is successful reclamation of the mine site itself (Deniseger and Kwong 1996). However, research is still needed to investigate whether copper has also been transported to the estuary.

Compared to other estuaries on the east coast of Vancouver Island (Campbell River estuary) and the lower mainland of British Columbia, the catches of juvenile salmon during this project were much lower than expected. Further studies are recommended on the juvenile salmon within the Courtenay River estuary and the surrounding area to establish whether the data collected in 1998 truly portrays the situation in this estuary.

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Table 1. Releases of juvenile salmon and trout into the Courtenay area from 1989 to 1998 by year and for all years combined.

Year	Chinook		Coho	Chum	Pink	Steelhead		Cutthroat	Total
	Summer	Fall				Summer	Winter		
1989	1,894,248	2,864,288	2,012,504	3,237,089	3,286,590	72,714	37,540	6,500	13,411,473
1990	313,639	3,617,928	2,353,236	2,846,983	1,810,771	65,323	49,963	2,441	11,060,284
1991	1,638,731	3,293,420	1,996,970	5,163,162	2,824,479	22,284	76,888	9,762	15,025,696
1992	1,052,115	1,163,536	2,213,993	5,196,962	2,239,445	63,905	53,650	0	11,983,606
1993	702,884	1,401,295	537,186	4,915,005	2,531,984	30,369	29,015	13,524	10,161,262
1994	382,377	527,497	1,555,057	3,783,616	2,093,411	94,731	29,220	7,156	8,473,065
1995	482,355	1,881,064	1,373,466	5,032,631	2,627,774	9,731	13,484	725	11,421,230
1996	256,878	990,579	1,948,009	4,622,023	2,328,848	17,906	1,696	124	10,166,063
1997	176,985	851,168	1,333,389	3,889,786	2,023,626	43,989	0	0	8,318,943
1998	406,013	961,674	1,101,177	5,769,448	2,175,938	41,575	48,772	1064	10,505,661
Total	7,306,225	17,552,449	16,424,987	44,456,705	23,942,866	462,527	340,228	41,296	110,527,283
Mean ± 1SE	730,622.5 ±190,784.1	1,755,244.9 ± 351,122.2	1,642,498.7 ±178,820.9	4,445,670.5 ±301,684.1	2,394,286.6 ± 137,399.0	46,252.7 ± 8,638.9	34,022.8 ± 7,731.0	4,129.6 ± 1523.0	11,052,728.3 ± 652,843.4

Table 2. Releases of juvenile salmonids during 1998 including stock of origin, release site and date, and fish mean length and weight (see section on Courtenay area for explanation of stage designations).

Stock of origin	Species and run	Stage	Site of release	Date of release	Number tagged (CWT)	Adipose clipped only	Number unmarked	Total releases	Mean Length (mm)	Mean Weight (g)
Little Qualicum River	Fall chinook	Seapen 0+	Comox Bay	June 4	24,396	664	171,864	196,924	87.0	7.0
Little Qualicum River	Fall chinook	Smolt 0+	Puntledge River	June 5 -7	24,681	895	633,321	658,897	85.0	6.5
Puntledge River	Fall chinook	Smolt 0+	Puntledge River	June 5-7	28,785	1,698	75,370	105,853	86.1	6.9
Puntledge River	Summer chinook	Smolt 0+	Puntledge River up	June 2-7	29,294	924	223,703	253,921	84.4	6.1
Puntledge River	Summer chinook	Seapen 0+	Comox Bay	June 4	28,802	1,484	121,806	152,092	82.0	6.1
Total chinook								1,367,687		
Puntledge River	Fall chum	Fed FW	Puntledge River	April 2-7	0	0	1,020,198	1,020,198	-	0.5
Puntledge River	Fall chum	Fed FW	Puntledge River	April 24-May 7	68,848	12,566	4,667,836	4,749,250	55.0	1.2
Total chum								5,769,448		

Table 2 (cont'd).

Stock of origin	Species and run	Stage	Site of release	Date of release	Number tagged (CWT)	Adipose clipped only	Number unmarked	Total releases	Mean Length (mm)	Mean Weight (g)
Millard Creek	Fall coho	Fed Spr	Millard Creek (b)	June	0	0	15,500	15,500	-	1.5
Puntledge River	Fall coho	Fed Spr	Brooklyn Creek (a)	May	0	0	774	774	-	2.0
Puntledge River	Fall coho	Fed Spr	Comox Lake (c)	June 3-8	13,443	1,730	59,026	74,199	66.4	3.3
Puntledge River	Fall coho	Fed Spr	Cruickshank River (c)	June 16-17	15,287	62	59,014	74,363	71.8	4.4
Puntledge River	Fall coho	Fed Spr	Dove Creek (a)	May	0	0	19	19	-	2.0
Puntledge River	Fall coho	Fed Spr	Eric Creek (c)	June 16	14,871	382	59,014	74,267	71.8	4.4
Puntledge River	Fall coho	Fed Spr	Hobson Creek (a)	May	0	0	270	270	-	2.0
Puntledge River	Fall coho	Fed Spr	Morrison Creek (a)	May	0	0	229	229	-	2.0
Puntledge River	Fall coho	Fed Spr	Portugese Creek (a)	May	0	0	177	177	-	2.0
Puntledge River	Fall coho	Fed Spr	Rees Creek (c)	June 16	14,859	571	59,014	74,444	71.8	4.4

Table 2 (cont'd).

Stock of origin	Species and run	Stage	Site of release	Date of release	Number tagged (CWT)	Adipose clipped only	Number unmarked	Total releases	Mean Length (mm)	Mean Weight (g)
Puntledge River	Fall coho	Smolts	Puntledge River	May 11	9,206	216	106,071	115,493	121.3	18.2
Puntledge River	Fall coho	Smolts	Puntledge River	May 19	9,260	189	123,207	132,656	129.4	22.9
Puntledge River	Fall coho	Smolts	Puntledge River	May 11-May 19	0	0	166,095	166,095	125	19.0
Puntledge River	Fall coho	Smolts	Puntledge River	May 11	9,661	127	122,253	132,041	124.6	19.6
Puntledge River	Fall coho	Smolts	Puntledge River	May 19	9,499	355	130,634	140,488	123.8	20.0
Roy Creek	Fall coho	Fed Spr	Roy Creek (b)	May	0	0	25,000	25,000	-	2.0
Roy Creek	Fall coho	Fed Spr	Roy Creek (a)	May	0	0	162	162	-	2.0
Trent River	Fall coho	Fed Spr	Trent River (b)	June	0	0	75,000	75,000	-	2.0
Total coho								1,101,177		
Puntledge River	Fall cutthroat	Smolt 1+	Puntledge River	May 12	1,064	0	0	1,064	195.0	80.8
Total cutthroat								1,064		

Table 2 (cont'd).

Stock of origin	Species and run	Stage	Site of release	Date of release	Number tagged (CWT)	Adipose clipped only	Number unmarked	Total releases	Mean Length (mm)	Mean Weight (g)
Quinsam River	Fall pink	Seapen	Comox Bay	April 21	0	0	1,498,647	1,498,647	54.9	1.6
Quinsam River	Fall pink	Unfed	Puntledge River	Jan 5-Apr 6	0	0	677,291	677,291	31.9	0.21
Total pink								2,175,938		
Puntledge River	Summer steelhead	Sm Sr1+	Puntledge River up	May 7-12	41,575	0	0	41,575	187.8	61.3
Puntledge River	Winter steelhead	Sm Wr 1+	Puntledge River	May 8-12	48,772	0	0	48,772	195	85.0
Total steelhead								90,347		
Total salmonid releases								10,505,661		

(a) Classroom incubated
(b) Fed fry release
(c) Colonization

Table 3. Locations and descriptions of sites sampled during the 1998 survey.

Site No.	Description
1.	Located in upper estuary at mouth of small dredged boat slough. Moderate to steep slope, fine mud substrate. River banks covered in grasses and small shrubs near the water's edge, large trees less than 1 m back from water on upper shore. Swift currents.
2.	Mouth of Trent River (Gartley Point). Flat sandy substrate with medium to large rocks, mud offshore. Grasses and shrubs 10 m on upper shore. *Fucus* sp., barnacles, *Ulva* sp.
3.	Located at Royston. Very shallow, pebble and mid-sized rocks. No vegetation on the beach. Reported as a high faecal coliform area.
4.	Site at union of riprap breakwater and shoreline, west side of estuary. Rocky/gravel substrate, very gradual slope. *Fucus* sp., and large eelgrass bed offshore.
5.	Below Hilton road. Sandy and muddy substrate with large rocks covered in barnacles. Very shallow, little slope, some eelgrass and debris near shore.
6.	Site on north side of Goose Spit. Sandy substrate, steep slope, some marshgrass on upper shore. Eelgrass bed offshore. Swift currents.
7.	Located at mouth of Brooklyn Creek, adjacent to residential area. Mid-size gravel to sand/mud offshore, flat. *Fucus* sp. and *Ulva* sp. in intertidal area.
8.	Site within Comox Marina, at Grid #2. Large rocks, pebble and sand mix on shore, steep slope into the water. Little intertidal vegetation, some small vegetation in high intertidal area. Very sheltered.
9.	North of Comox Marina, in front of condominium complex. Large riprap breakwater with steep slope to gravel/sand/mud in low intertidal area. Moderate slope offshore, no vegetation in intertidal or upper shore.

Table 3 (cont'd).

Site No.	Description
10.	Site on shore of Indian Reserve No. 1, on east side of the river channel. Fine mud and sand substrate, marshgrass in backshore, shells, some rocks and gravel in intertidal area. Moderate slope, occasional swift current.
11.	Located at mouth of Duck Slough in upper estuary. Gravel substrate, moderate slope, marshgrass on upper shore.
12.	Sampled adjacent to airpark, on west side of river channel. Steep gravel beach, marsh grass in backshore. Swift current.
13.	Site on west side of river channel, below Tenth St., across river from site 1. Steep slope, gravel substrate, tall, dense marshgrass to waterline, trees in upper shore 1 m from waterline. Swift currents.
14.	Sampled within abandoned dredged boat basin on west side of river channel, north of boat launch. Very steep slope, tall marshgrass, trees to waterline. *Fucus* sp., *Ulva* sp.
15.	Site on south side of Goose Spit. Gentle sloping mid sized gravel, substrate became sandy at low intertidal/subtidal. Sand dollars, eelgrass in low intertidal/subtidal area, tall grasses and evergreens in backshore, about 5 m from shore. Exposed.
16.	Narrow, small slough connected to sewage lagoon. Shallow, muddy substrate, marsh grass in upper shore.
17.	Sampled on riverbank, across from Lewis Park. Moderately sloping river banks, sandy substrate covered with marsh grass. Swift current.

Table 4. Salinity, temperature and dissolved oxygen ranges and mean values ± 1SE in the upper and lower regions of the estuary and for the estuary as a whole (total number of samples in brackets).

Region of estuary	Site #	Dates sampled	Total # samples	Depth (m)	Temperature ranges (°C)	Salinity ranges (‰)	Oxygen ranges (mg/l)
Upper	1	3 Jun - 29 July	10	Surface to 2.0	12.0-22.7	0	7.5-9.6
"	10	21 May - 15 July	5	Surface	15.8-21.0	1.0-20.0	8.1-10.6
"	11	21 May - 29 July	10	Surface to 1.0	13.5-23.2	0-6.5	7.2-9.0
"	12	21 May - 15 July	10	Surface to 1.0	12.5-20.3	0 - 0.5	8.6-10.4
"	13	3 Jun - 29 Jun	5	Surface to 1.0	12.0-18.2	0	9.0-10.7
"	14	4 Jun - 29 July	9	Surface to 1.5	16.4-23.5	0-6.5	5.4-8.6
"	16	17 Jun	2	Surface to 0.5	16.5-17.5	0 - 0.1	7.2-7.5
"	17	29 Jun - 29 July	6	Surface to 3.0	18.9-22.1	0 - 0.5	7.8-8.6
"	All	21 May - 29 July	57	Surface to 3.0	12.0-23.5	0-20.0	5.4-10.7
All Upper	Mean ± 1SE		57	Surface to 3.0	18.1 ± 0.4 (57)	1.1± 0.4 (57)	8.6 ± 0.2 (45)
Lower	2	4 Jun - 29 July	5	Surface	16.8-23.1	7.3-22.5	7.0-9.8
"	3	3 Jun - 15 July	4	Surface	16.5-21.6	10.5-20.9	7.0-9.4
"	4	3 Jun - 29 July	6	Surface to 1.0	15.0-23.9	10.9-21.0	8.0-9.8
"	5	4 Jun - 15 July	4	Surface	12.3-22.0	8.0-29.2	7.5-8.2
"	6	3 Jun - 14 July	7	Surface to 2.0	16.8-21.4	18.5-23.5	7.4-10.0
"	7	21 May-14 July	4	Surface	15.5-18.2	19.6-24.0	7.1-8.5
"	8	21 May - 29 July	15	Surface to 3.0	16.0-24.8	9.8-25.0	6.5-10.0

Table 4 (cont'd).

Region of estuary	Site #	Dates sampled	Total # samples	Depth (m)	Temperature ranges (°C)	Salinity ranges (‰)	Oxygen ranges (mg/l)
Lower	9	21 May - 14 July	7	Surface to 1.0	15.0-22.5	18.0-26.0	7.4-9.4
"	15	4 Jun - 29 July	8	Surface to 2.0	15.8-23.7	18.8-24.5	7.4-10.6
	All	20 May - 29 July	60	Surface to 1.0	12.3-24.8	7.3-29.2	7.0-9.8
All Lower	Mean ± 1SE		60	Surface to 3.0	19.1 ± 0.4 (61)	19.3 ± 0.6 (61)	8.5 ± 0.2 (46)
All sites	Mean ± 1SE		118	Surface to 3.0	18.6 ± 0.3 (118)	10.5 ± 0.9 (118)	8.5 ± 0.1 (91)

Table 5. Results of one way ANOVA of temperatures, salinities and dissolved oxygen levels recorded in the two regions of the estuary during 1998.

Variable tested upper region vs. lower region	Number of samples		*F* value	*P* value
	Upper	Lower		
All salinities	57	61	545.0177	$P < 0.01$
Surface salinities	33	42	230.1805	$P < 0.01$
All temperatures	57	61	3.3212	Not significant
Surface temperatures	33	42	4.1366	$P < 0.05$
All dissolved oxygen	45	46	0.2363	Not significant
Surface dissolved oxygen	23	30	0.8042	Not significant

Table 6. Total catch of salmonids by species and CPUE for the upper, lower and both regions in the estuary.

Region Total # sets	Coho		Chinook		Chum		Steelhead		Cutthroat		Total salmon	
	Total catch	CPUE	Total catch	CPUE	Total catch	CPUE	Total catch	CPUE	Total catch	CPUE	Total catch	CPUE
Upper estuary 76 sets	124	1.63	302	3.97	114	1.50	21	0.28	7	0.09	568	7.47
Lower estuary 100 sets	67	0.67	46	0.46	48	0.48	4	0.04	1	0.01	166	1.66
Total 176 sets	191	1.09	348	1.98	162	0.92	25	0.14	8	0.05	734	4.17

Table 7. Each species of salmonid as a % of the total catch of salmonids in the upper, lower and both regions of the estuary.

Region	Upper estuary	Lower estuary	All regions
#samples	76	100	176
Species	% of catch	% of catch	% of catch
Coho	21.8	40.4	26.0
Chinook	53.2	27.7	47.4
Chum	20.1	28.9	22.1
Steelhead	3.7	2.4	3.4
Cutthroat	1.2	0.6	1.1

Table 8. Results of one way ANOVA of salmonid distribution in the upper and lower regions of the estuary.

Species	Number of samples		*F* value	*P* value	Sig.
	Upper	Lower			
Coho	76	100	2.2900	0.1320	NS
Chinook	76	100	13.5722	0.0003	$P < 0.01$
Chum	76	100	0.8825	0.3488	NS
Steelhead	76	100	5.7450	0.0176	$P < 0.05$
All salmonids	76	100	9.4017	0.0025	$P < 0.01$

Table 9. Mean salmonid lengths, weights and K-factors ± 1SE by species, site and region.

Region of estuary	Site	Species	Total # Measured	Mean ±1SE		
				Length	Weight	KC
Upper	1	Chinook	15	66.4±2.3	3.2±0.4	1.05±0.03
	10	Chinook	17	84.6±1.1	6.1±0.3	1.00±0.02
	11	Chinook	1	87	5.0	0.76
	"	Coho	17	72.5±4.2	4.5±1.0	0.99±0.03
	12	Chinook	11	82.5±1.7	5.8±0.4	1.01±0.02
	13	Chinook	10	72.8±5.3	4.5±0.8	1.05±0.04
	14	Chinook	5	57.2±0.9	1.9±0.1	1.03±0.06
	"	Coho	24	60.3±1.5	2.5±0.2	1.07±0.02
	"	Chum	1	57	1.5	0.81
	17	Chinook	29	75.4±2.7	4.8±0.4	1.01±0.02
	All	Chinook	88	75.4±1.4	4.7±0.2	1.02±0.01
	All	Coho	41	65.3±2.1	3.3±0.4	1.04±0.02
	All	All Salmon	130	72.1±1.2	4.3±0.2	1.02±0.01
Lower	2	Chinook	2	82.5	5.6	0.98
	"	Coho	1	68.0	3.2	1.02
	4	Chinook	4	86.3±5.5	7.0±1.2	1.05±0.04

Table 9 (cont'd).

Region of estuary	Site	Species	Total # Measured	Mean ±1SE		
				Length	Weight	KC
Lower	8	Chinook	18	73.4±2.3	4.2±0.5	1.03±0.02
	"	Coho	1	52.0	1.5	1.07
	9	Chinook	4	76.3±2.9	4.6±0.5	1.03±0.02
	15	Chinook	2	44.1	8.7	1.01
	All	Chinook	30	77.5±2.0	5.1±0.4	1.03±0.02
	All	Coho	2	60.0	2.4	1.05
	All	All salmon	32	76.4±2.0	4.9±0.4	1.03±0.01
Upper and lower	All	Chinook	118	75.9±1.2	4.8±0.2	1.02±0.01
"	All	Coho	43	65.1±2.1	3.3±0.4	1.04±0.02
"	All	All salmon	162	72.9±1.1	4.4±0.2	1.02±0.01

Table 10. Results of one way ANOVA of lengths, weights and condition factors for chinook and coho in the upper and lower regions of the estuary.

Species	Region	Factor	*F* value	*P* value	Sig.
Chinook	Upper vs. lower	Length	0.6241	0.4311	NS
"	"	Weight	0.6173	0.4337	NS
"	"	KC	0.1250	0.7243	NS
All salmon	"	Length	2.5724	0.1107	NS
"	"	Weight	2.2617	0.1346	NS
"	"	KC	0.0340	0.8540	NS
Chinook vs. coho	Upper estuary	Length	15.6725	0.0001	P<0.01
"	"	Weight	9.5394	0.0025	P<0.01
"	"	KC	0.9653	0.3277	NS

Table 11. Total catch and CPUE of dominant non-salmonids by common name for the upper, lower and both regions in the estuary.

Region Total # sets	Sculpin		Perch		Stickleback		Flatfish		Gunnel		Greenling		Prickleback		Sandlance	
	Total catch	CPUE	Total catch	CPUE	Total catch	CPUE	Total catch	CPUE	Total catch	CPUE	Total catch	CPUE	Total catch	CPUE	Total catch	CPUE
Upper estuary 76 sets	878	11.6	338	4.4	1419	18.7	284	3.7	17	0.2	4	0.05	0	0	1	0.01
Lower estuary 100 sets	2492	24.9	520	5.2	1528	15.3	476	4.8	109	1.1	16	0.2	59	0.6	890	9.0
Total 176 sets	3370	19.1	858	4.9	2947	16.7	760	4.3	126	0.7	20	0.1	59	0.3	891	5.1

Table 12. Each group of non-salmonid as a % of the total catch of non-salmonids in the upper, lower and both regions of the estuary.

Region	Upper estuary	Lower estuary	All regions
#samples	76	100	176
Group	% of catch	% of catch	% of catch
Sculpins	29.9	40.8	37.2
Perch	11.5	8.5	9.5
Stickleback	48.2	25.0	32.6
Flatfish	9.7	7.8	8.4
Others	0.7	17.9	12.3

Table 13. Results of one way ANOVA of non-salmonid distribution in the upper and lower regions of the estuary.

Group	Number of samples		*F* value	*P* value	Sig.
	Upper	Lower			
Sculpins	76	100	7.3324	0.0074	P<0.01
Perch	76	100	0.1139	0.7361	NS
Stickleback	76	100	0.0343	0.8531	NS
Flatfish	76	100	0.4884	0.4856	NS

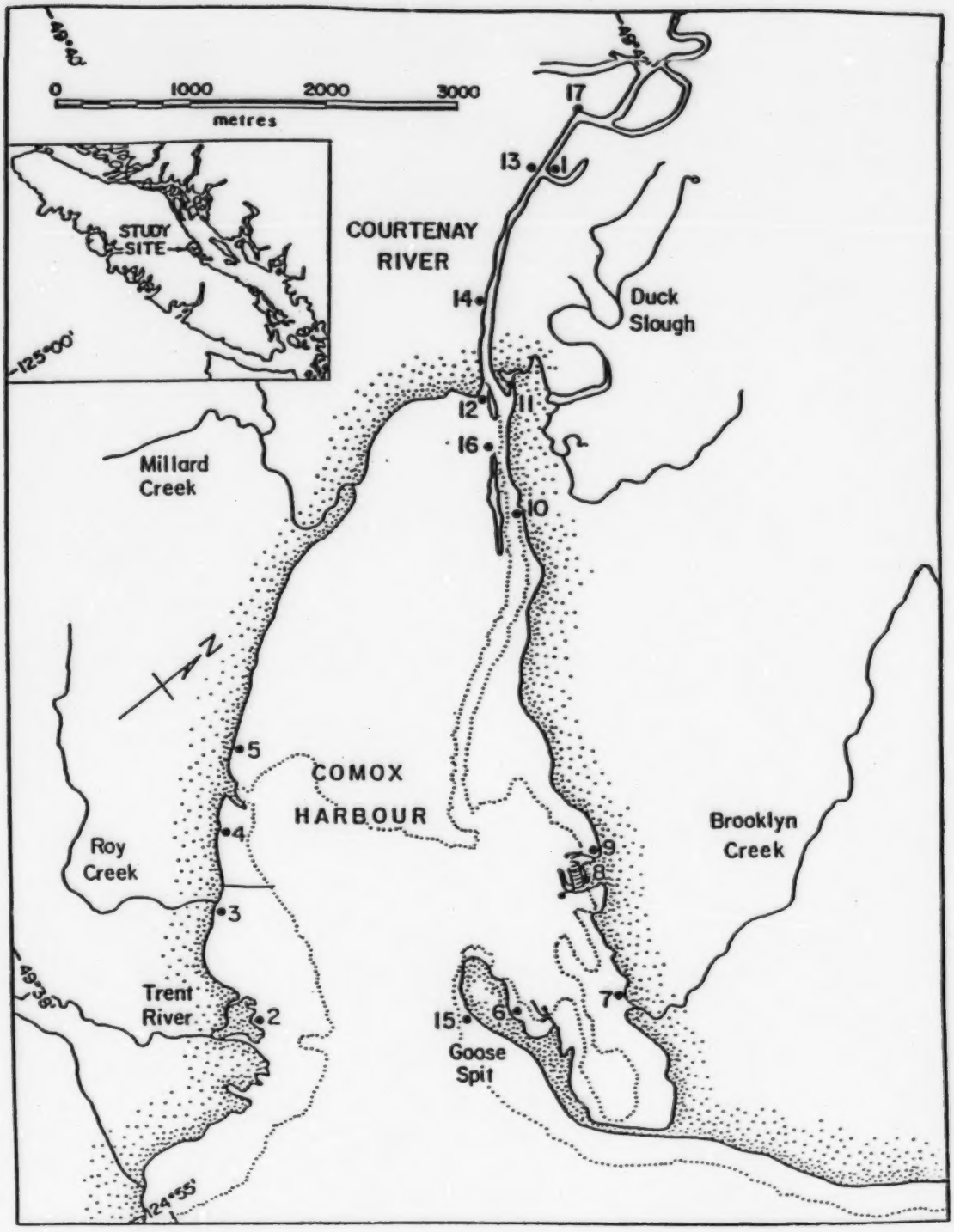

Fig. 1. Sites sampled in the Courtenay River estuary during the 1998 survey.

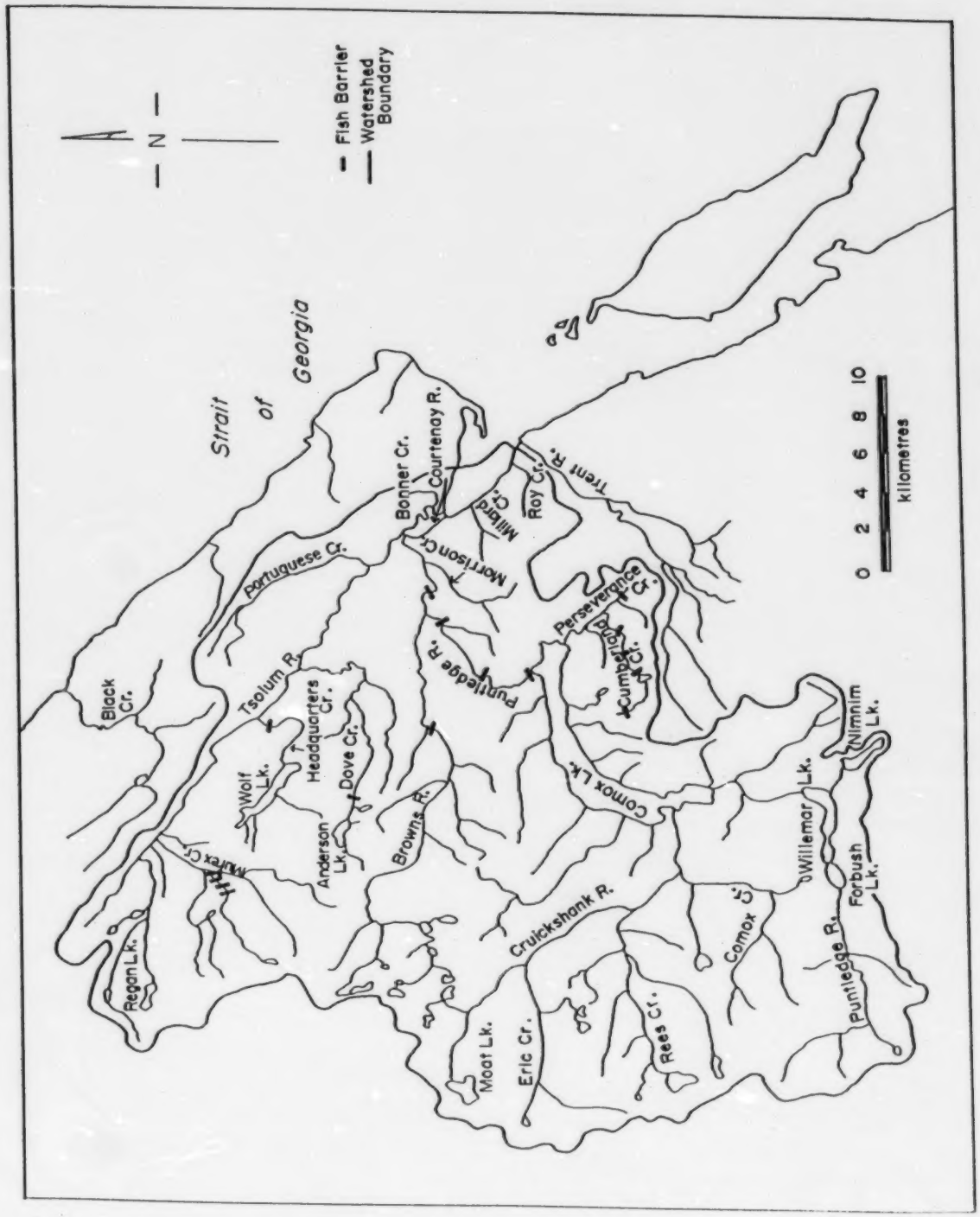

Fig. 2. Map of the watershed of the Courtenay River.

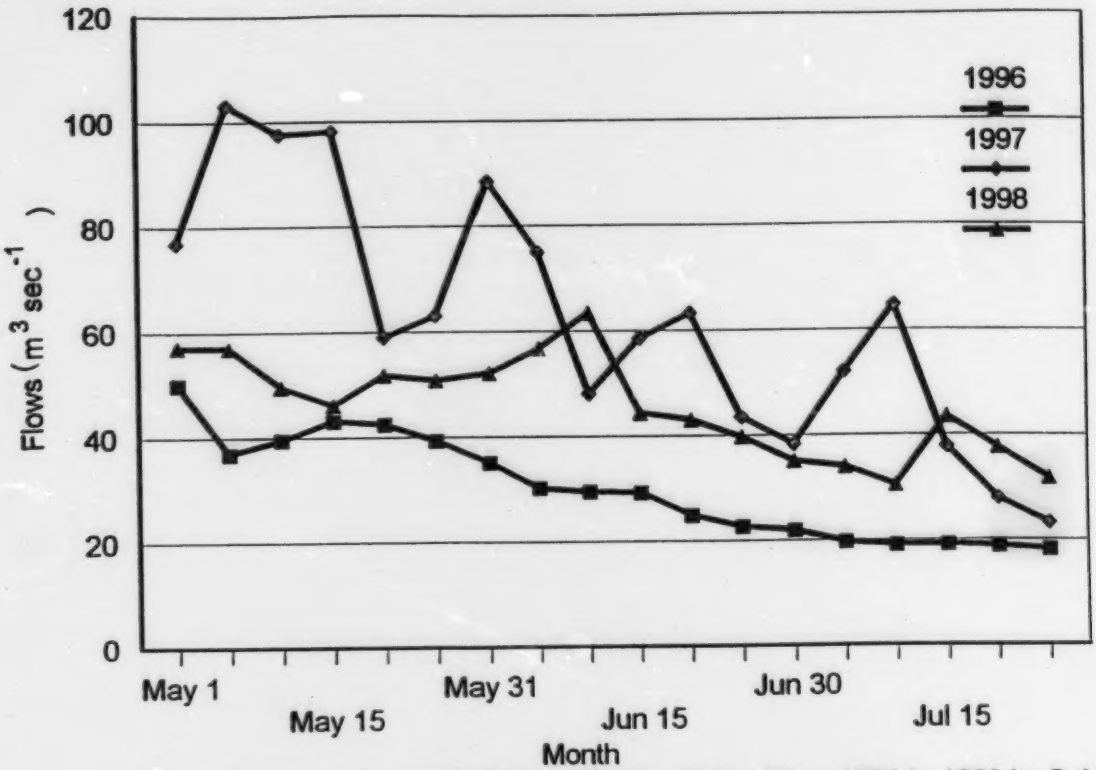

Fig. 3. Spring and summer flows in the Puntledge River 1996 to 1998 by 5 day averages.

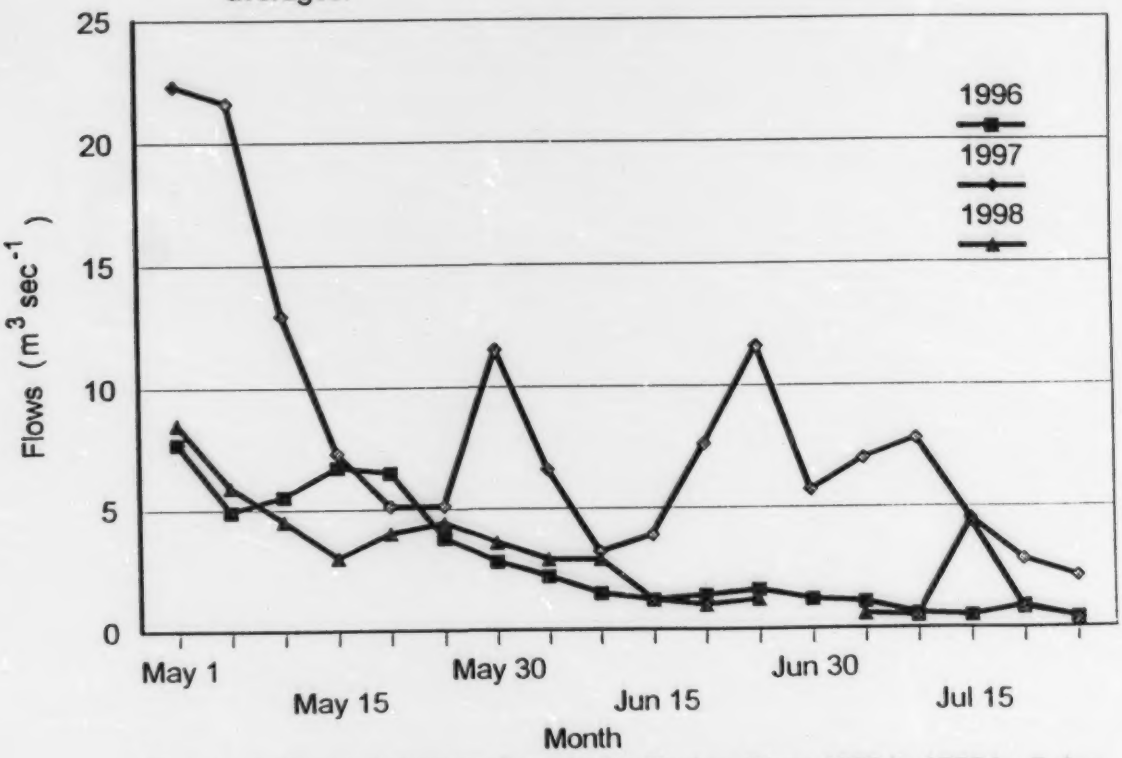

Fig. 4. Spring and summer flows in the Tsolum River 1996 to 1998 by 5 day averages.

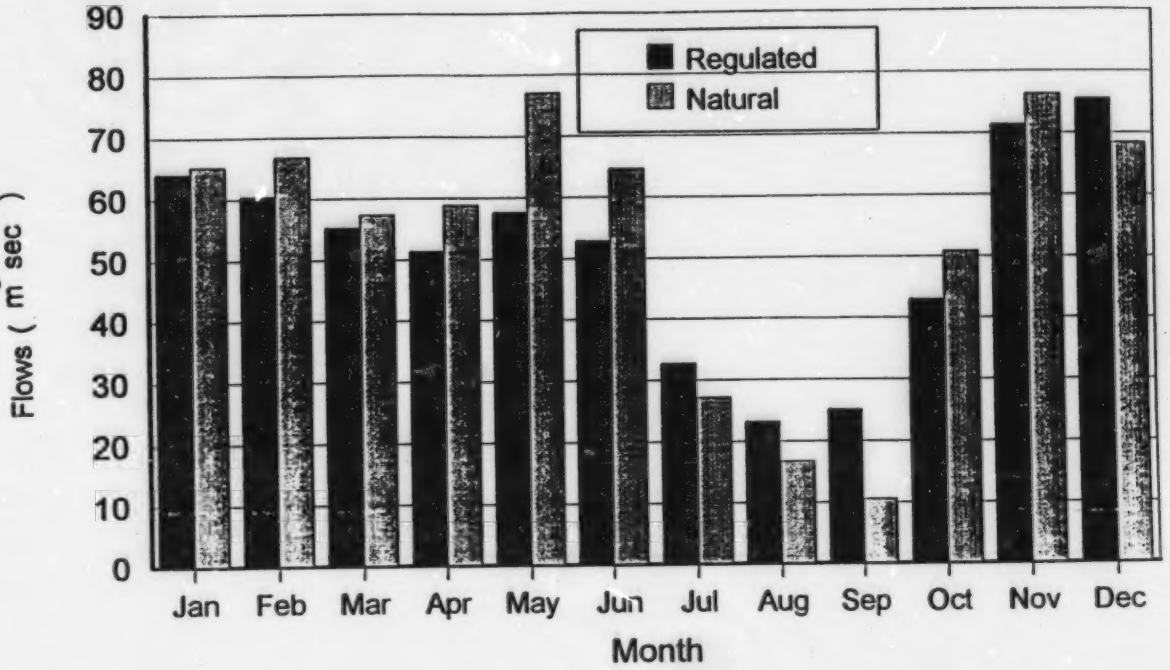

Fig. 5. Natural and regulated flows in the Courtenay River as determined from historical flow data (from Riddell and Bryden 1996).

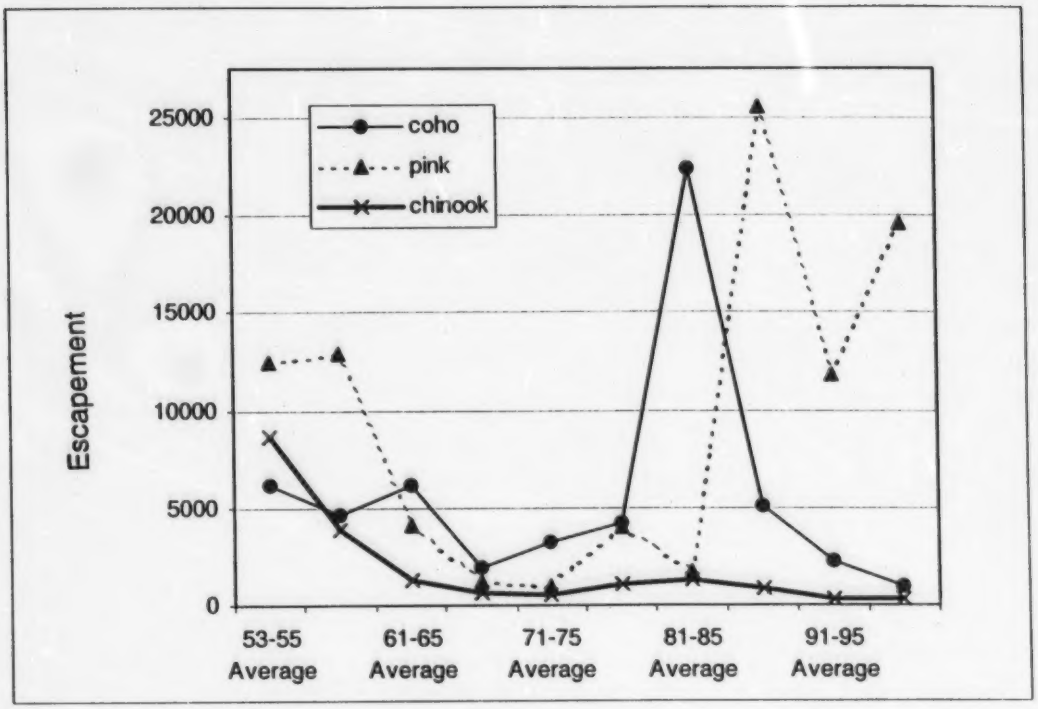

Fig. 6. Escapement of coho, pink and chinook to the Puntledge River 1953-1997.

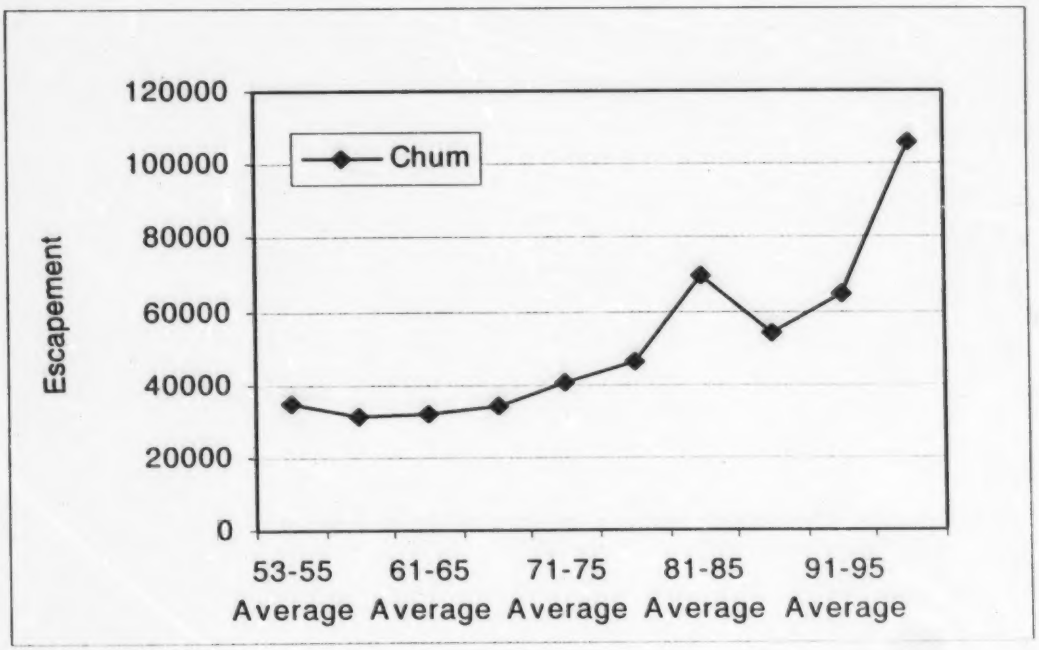

Fig. 7. Escapement of chum to the Puntledge River 1953- 1997.

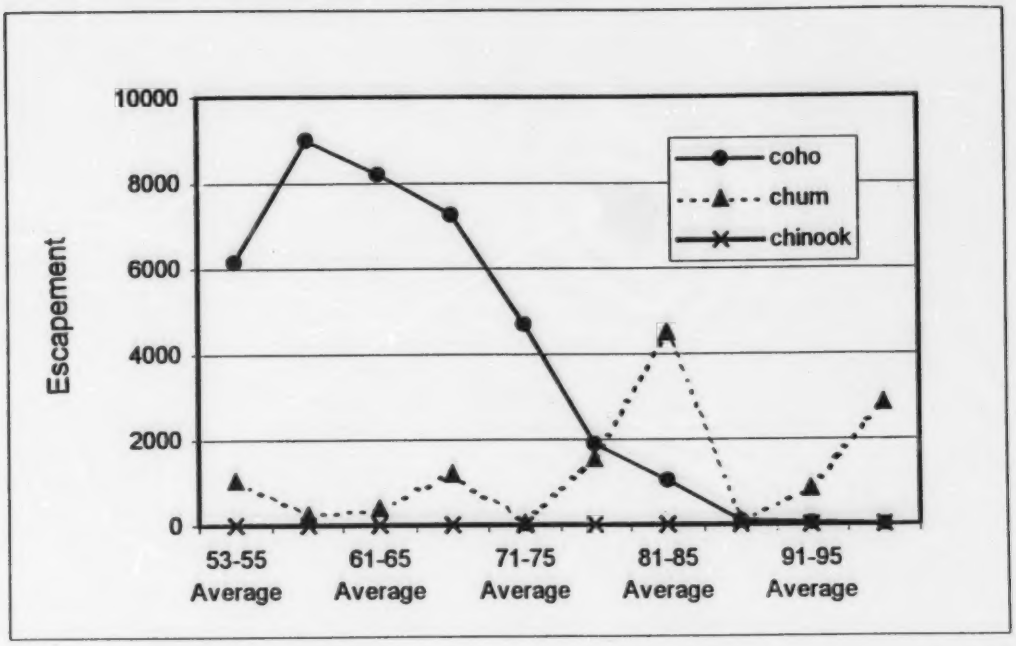

Fig.8. Escapement of coho, chum and chinook to the Tsolum River 1953-1997.

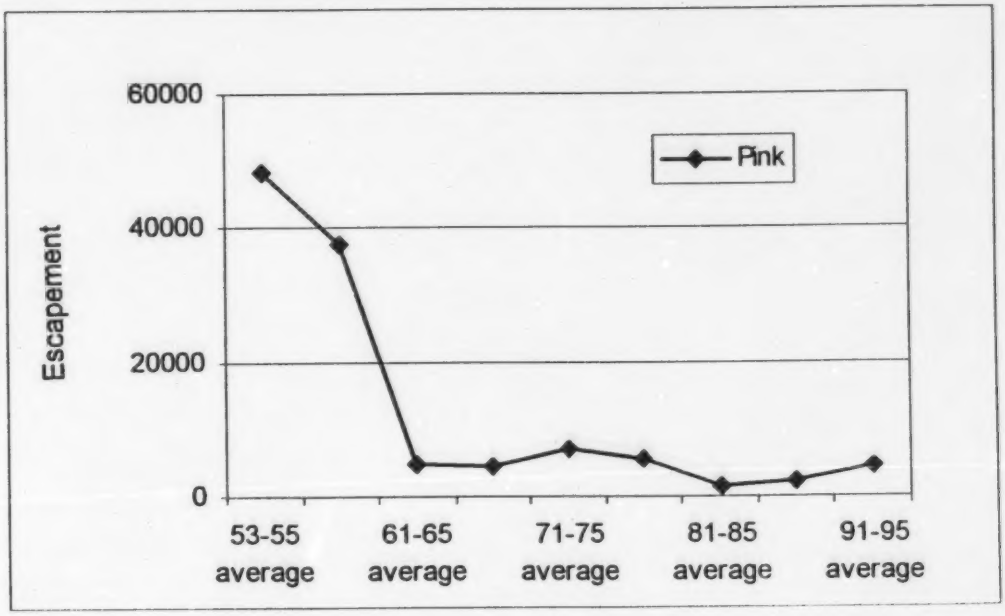

Fig. 9. Escapement of pink to the Tsolum River 1953-1997.

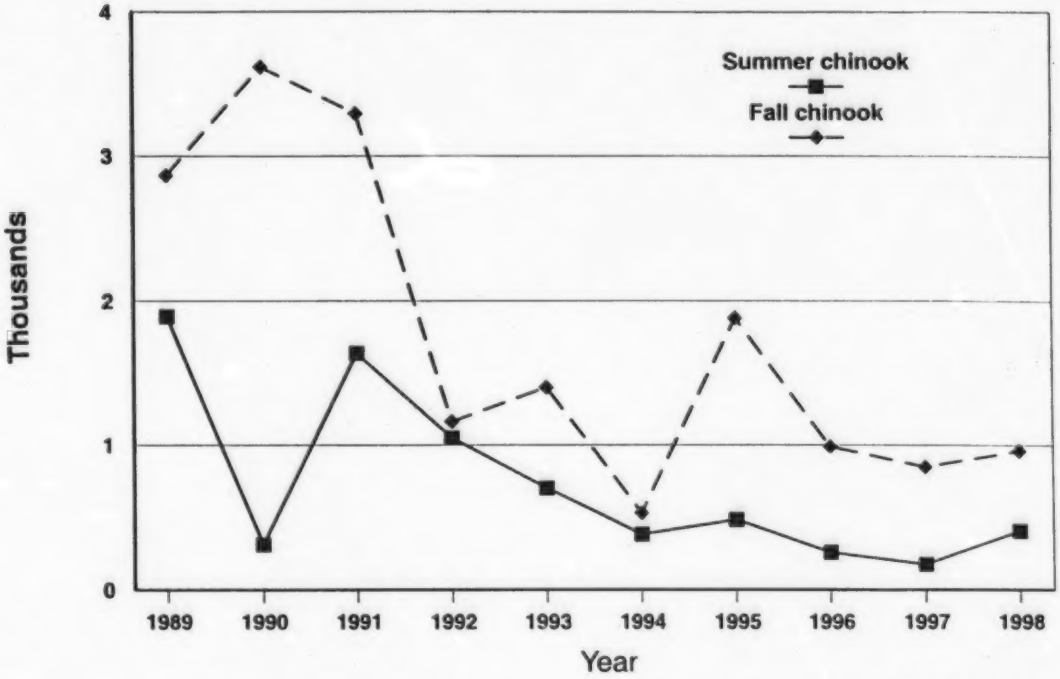

Fig. 10. Releases of juvenile summer and fall chinook into the Courtenay area from 1989 -1998.

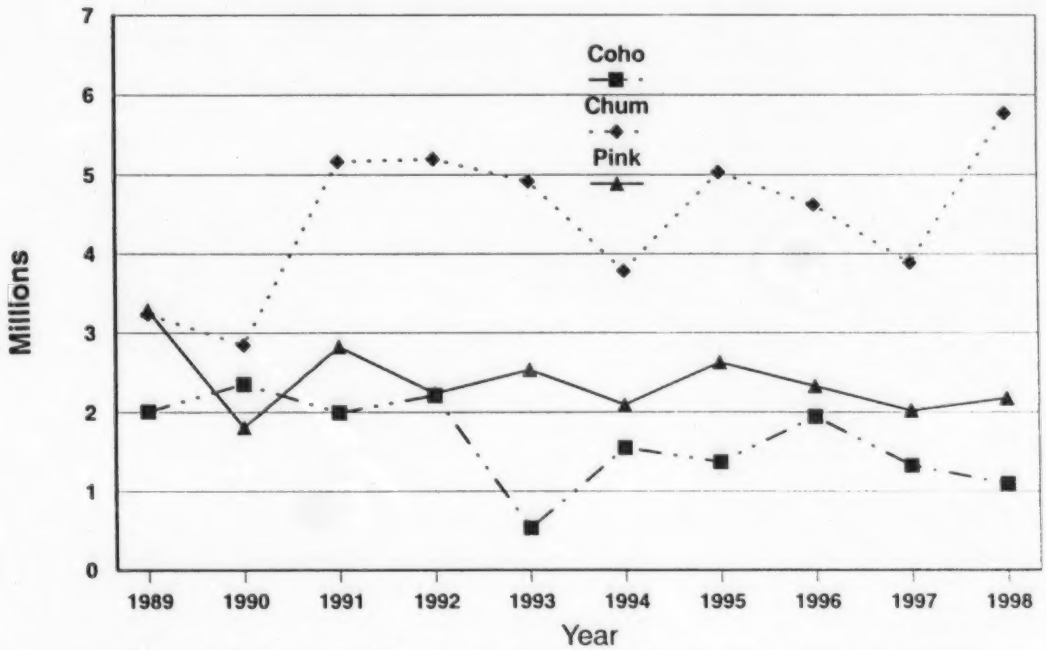

Fig. 11. Releases of juvenile coho, chum and pink into the Courtenay area from 1989 -1998.

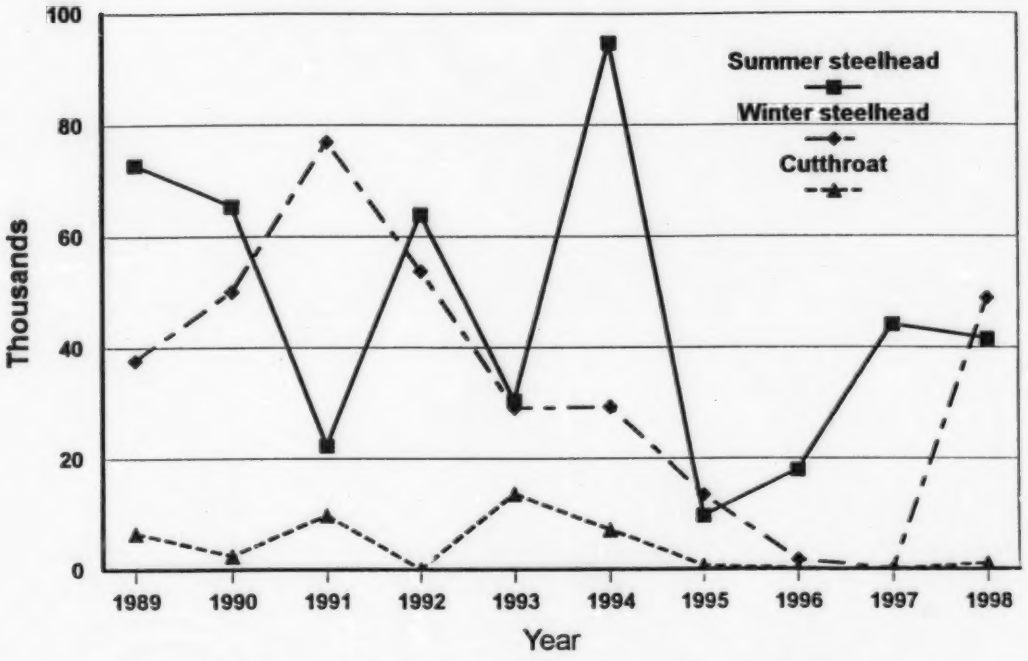

Fig. 12. Releases of juvenile summer and winter steelhead and cutthroat trout into the Courtenay area from 1989-1998.

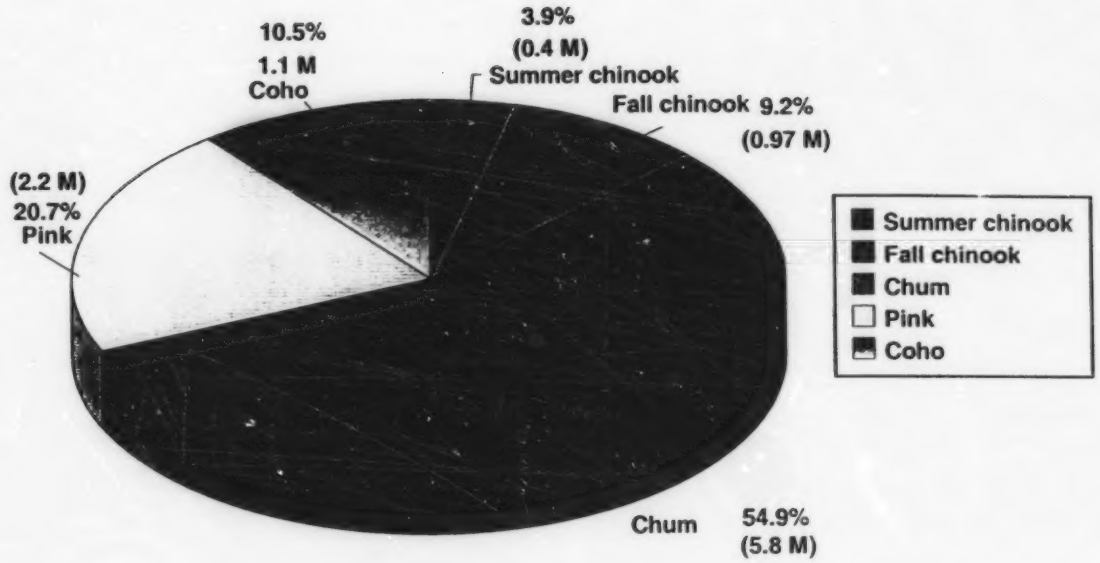

Fig. 13. Releases of juvenile summer and fall chinook, chum, pink and coho into the Courtenay area during 1998 and the percentage of the total releases for these species.

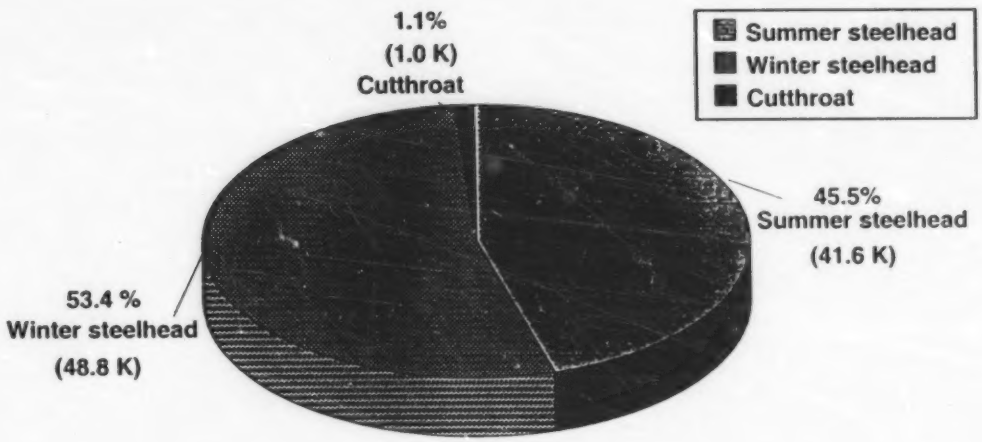

Fig. 14. Releases of juvenile summer and winter steelhead and cutthroat trout into the Courtenay area during 1998 and the percentage of the total releases for these species.

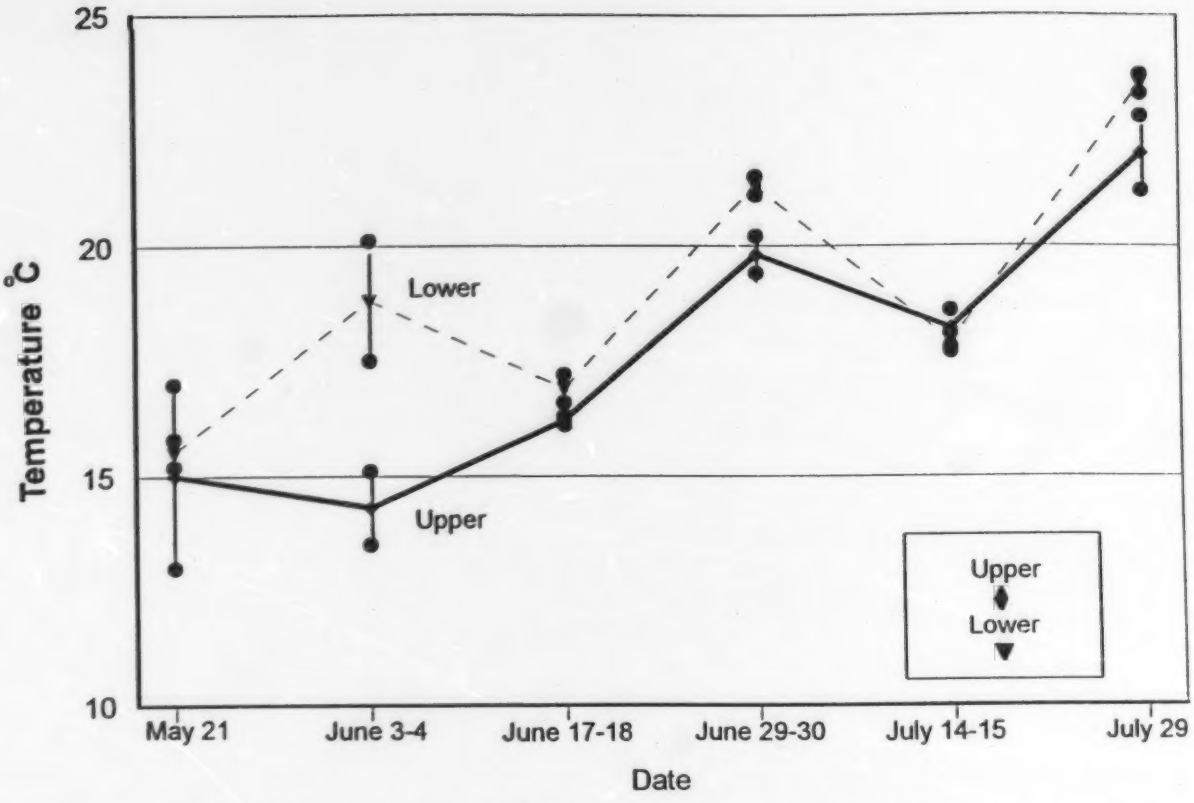

Fig. 15. Mean temperatures (^{0}C) $\pm$ 1SE recorded at the surface in the upper and lower regions of the estuary by sampling date.

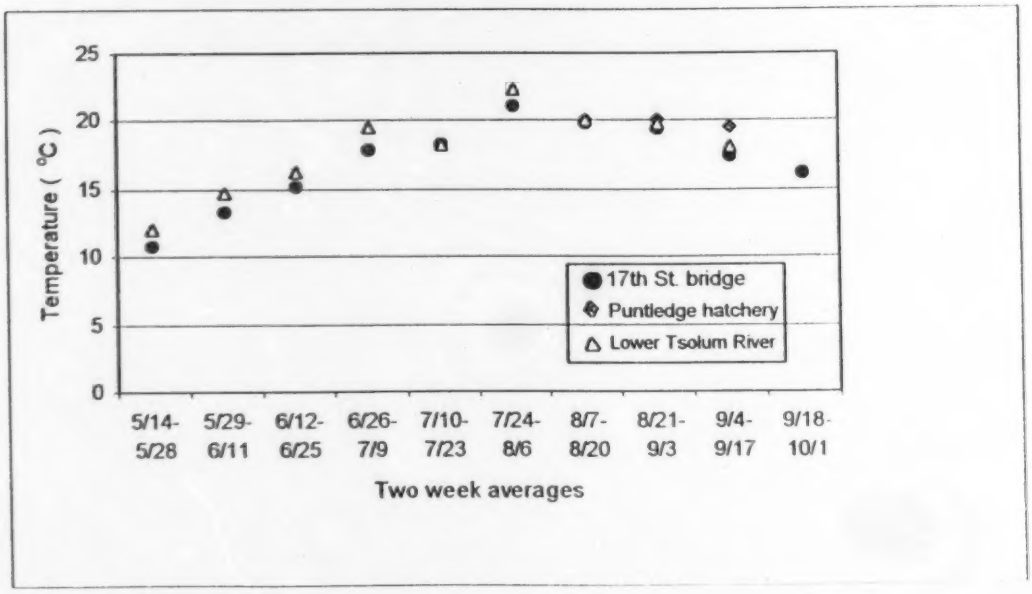

Fig. 16. Temperatures (^{0}C) recorded from May to October, 1998, by three data loggers located in the Puntledge, Tsolum and Courtenay rivers.

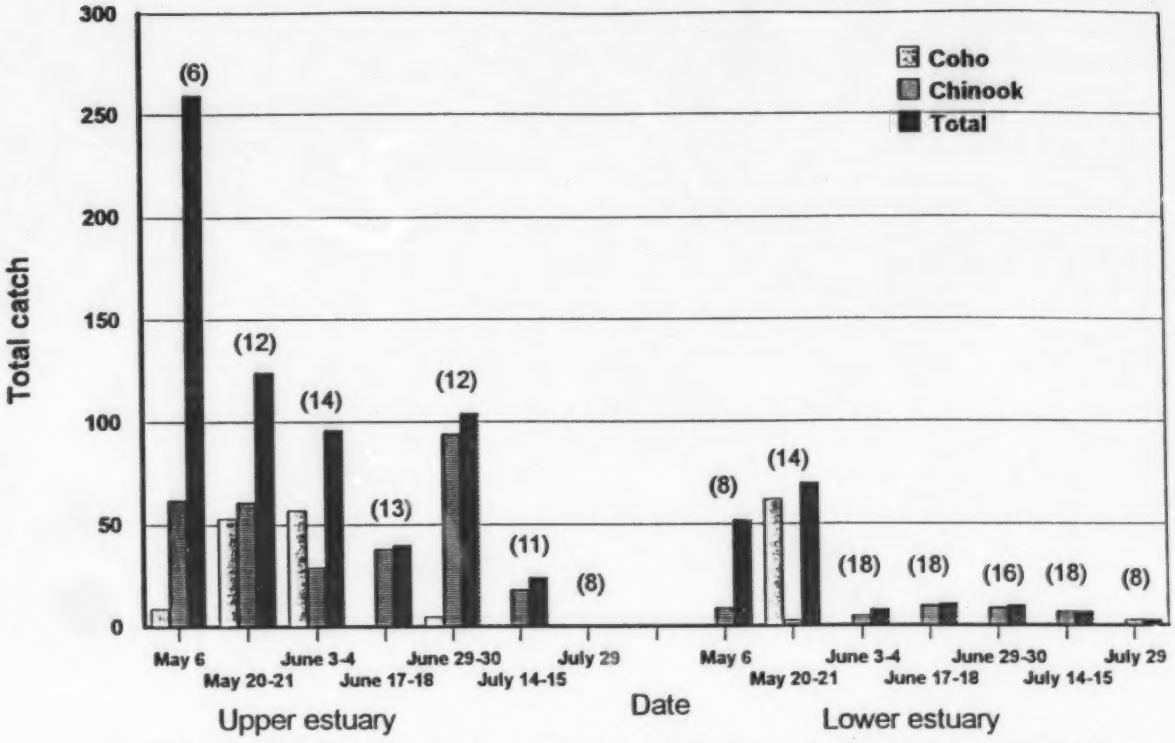

Fig. 17. Total catch of coho, chinook and all salmon by trip in the upper and lower regions of the estuary (number of beach seine sets in brackets).

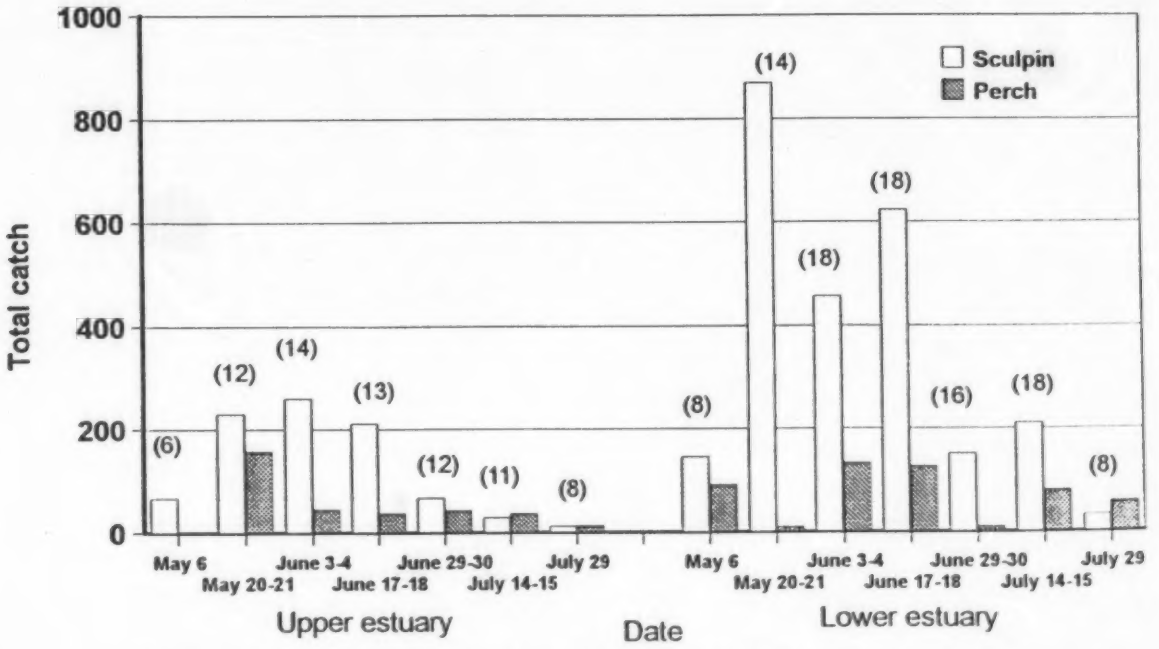

Fig. 18. Total catch of sculpins and perch by trip in the upper and lower regions of the estuary (number of beach seine sets in brackets).

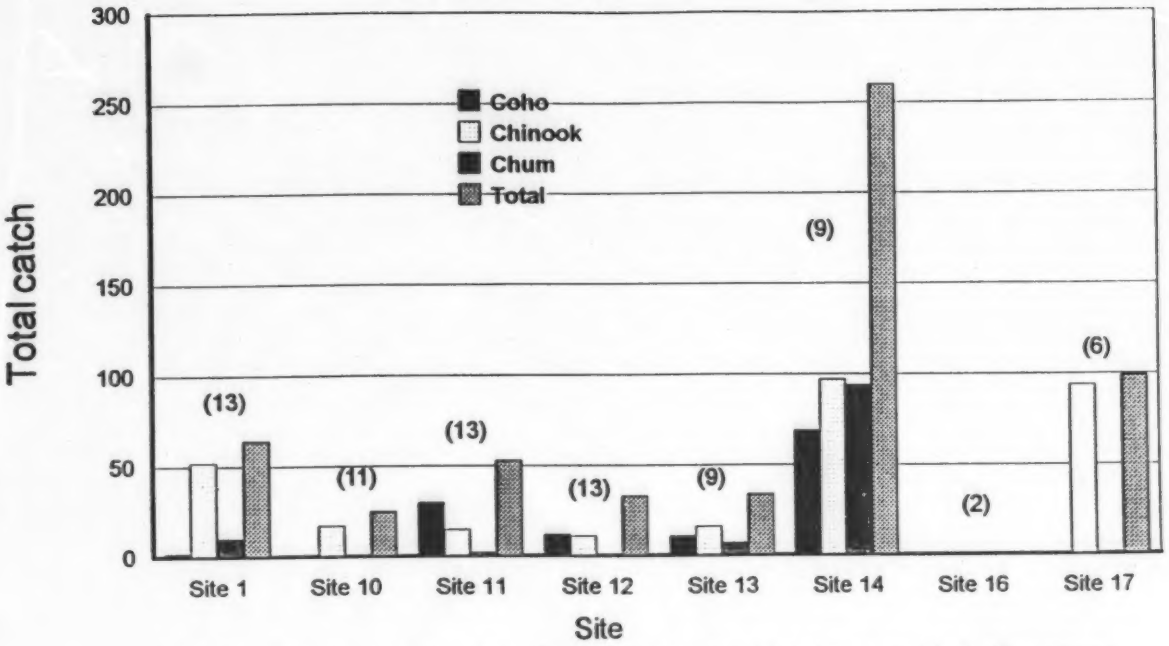

Fig. 19. Total catch of coho, chinook, chum and total salmonids in the upper estuary by site (number of beach seine sets in brackets).

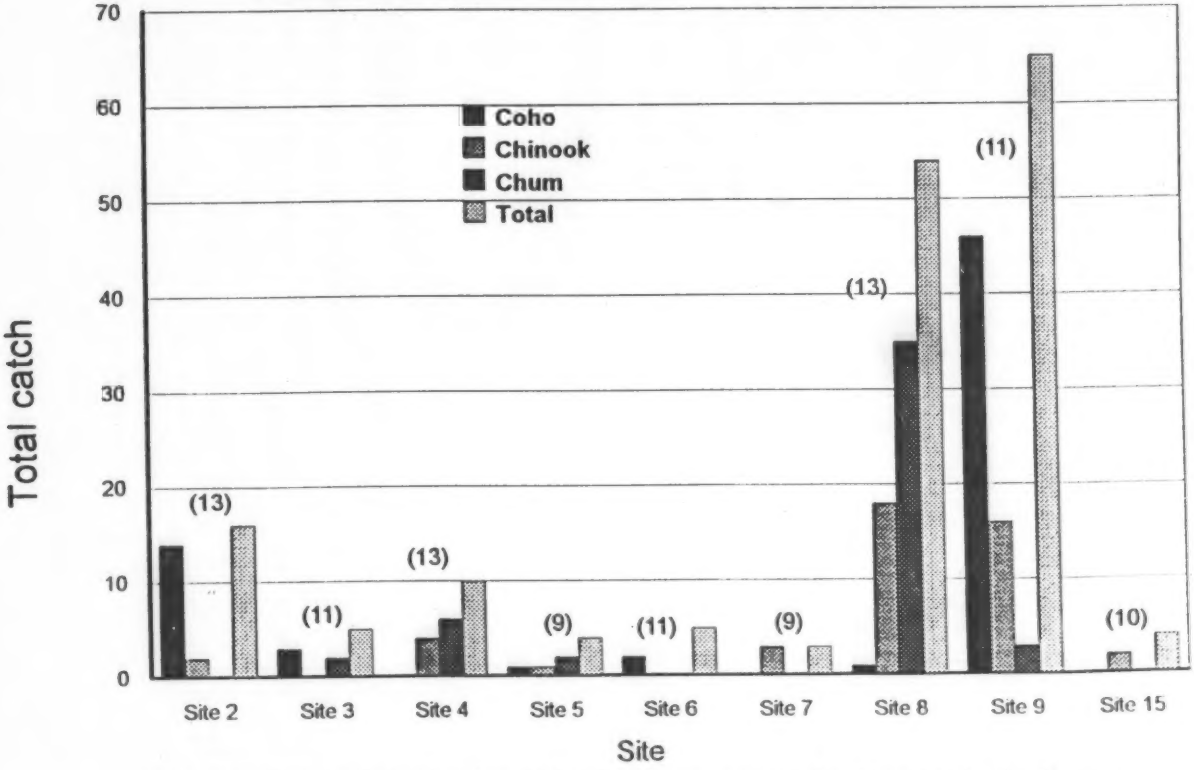

Fig. 20. Total catch of coho, chinook, chum and total salmonids in the lower estuary by site (number of beach seine sites in brackets).